Appendix A

Data Collection Forms

Appendix A

Data Collection Forms

This appendix presents two items related to collecting information on the contaminant inventories.

The first item is a blank, five-page data collection form. One data form was completed for each identified waste stream disposed of in the Subsurface Disposal Area (SDA). Continuation pages were added to the form as necessary. The Contaminant Inventory Database for Risk Assessment (CIDRA) database was modeled after this form. Completed forms for all identified waste streams are stored in CIDRA and constitute Appendix B of this report.

The second item is a list of the general physical forms for waste buried in the SDA. The list can be used in the database compilation of the inventory to rollup all waste streams having a similar physical form, regardless of the generator or building that produced the waste.

DATA INPUT FOR HISTORICAL DATA TASK FOR RWMC SUBSURFACE DISPOSAL AREA

PART A - GENERAL INFORMATION

1. Preparer ______________________

2. Date prepared ______________________

3. Generator ______________________
(area or contractor - use code from attached list)

4. Particular facility ______________________
(building number - use code from attached list)

5. Number of the waste stream from this facility ________

6. Waste stream ______________________

7. Type of radioactive waste (check box)
☐ TRU or suspect TRU
☐ LLW
☐ non-radioactive

8. Actual years disposed of at SDA
Starting year ______ Ending year ______

9. Waste stream volume
Amount ____________ Units ____________
Check box: ☐ annual or ☐ total over all years
Check box: ☐ container volume or ☐ waste volume

10. Comments (specify number of pertinent question) ______________________

PART B - WASTE STREAM CHARACTERISTICS

1. General physical form (see attached list)

☐ other (specify) ______

2. Details on physical form (particularly confinement related)

3. Chemical form ______

4. Inner packaging: ☐ plastic bag ☐ plastic liner ☐ metal liner
☐ none ☐ other (specify) ______

5. Waste container type (see attached list)

6. Other characteristics of interest ______

7. Comments (specify number of pertinent question) ______

PART C - NONRADIOLOGICAL CONTAMINANTS

For each contaminant, complete at least one line on the following table. If any entries for that contaminant vary by year, fill out additional lines as needed to cover the varying entries for different years. For example, if the annual quantity disposed was x kg for 1952–56 and y kg for 1957–84, use two lines to handle this situation.

Contaminant and CAS Registry Number	Physical Form	Chemical Form	(A)Annual/ (T)Total Quantity	Units	Begin Year	End Year	Samples? Y/N*	Minimum Value or No. of Samples*	Maximum Value or Std. Dev.*	Basis for Uncertainty

* If sample data are available, mark Y in the column titled "Samples?" and provide number of samples in the next column and standard deviation in the next column. If not, mark N and give the minimum value and maximum value.

Additional information or explanations (indicate pertinent contaminant)________________

PART D - RADIOLOGICAL CONTAMINANTS

Radionuclide	Physical Form	Chemical Form	(A)Annual/ (T)Total Quantity	Units	Begin Year	End Year	Samples? Y/N*	Minimum Value or No. of Samples*	Maximum Value or Std. Dev.*	Basis for Uncertainty

* If sample data are available, mark Y in the column titled "Samples?" and provide number of samples in the next column and standard deviation in the next column. If not, Mark N and give minimum value and maximum value.

Additional information or explanations (indicate pertinent contaminant). ______________________________

PART E - SOURCES OF INFORMATION AND UNCERTAINTIES

1. Type of source of information (check box)

☐ RWMIS ☐ other database
☐ sample analysis data
☐ operating records ☐ interview
☐ expert judgment ☐ reports
☐ other (specify) ____________

2. Details concerning source [names, report no., dates, etc.]

3. Do the estimates of contaminant quantities in Part C and D represent: (check box)

☐ best estimate
☐ worst case
☐ other (specify) ____________

4. If other than best estimate, explain why ____________

5. Do the data conflict with RWMIS?

☐ no
☐ yes

6. If yes, explain why ____________

7. Major unknowns in inventories of contaminants ____________

8. Key assumptions used to deal with the unknowns ____________

CONTINUATION PAGE

Continuation of Part ______________, Column or Question Number or Title ______________________________

GENERAL PHYSICAL FORMS FOR
WASTE BURIED IN THE SUBSURFACE DISPOSAL AREA

Number	Form
1	Irradiated fuel rods from experiments
2	Irradiated fuel from experiments
3	Unirradiated fuel from experiments
4	Irradiated end boxes
5	Other core, reactor vessel, and loop components
6	Ventilation systems
7	Lead
8	Beryllium
9	Zirconium
10	Other scrap metals
11	Sludge
12	Resin
13	Vermiculite and other sorbents
14	Evaporated salts
15	Other liquid setups
16	Graphite
17	Reactive metals
21	Combustibles (paper, cloth, wood, etc.)
22	High-efficiency particulate air filters
23	Other filters
24	Biological waste
31	Radiation sources
41	Concrete, brick, asphalt
42	Glass
43	Soil
44	Plastics
45	Rubber
46	Soot, ash
47	Asbestos
51	Liquids
52	Unknown
53	Other

Appendix B

Complete Printout of the Contaminant Inventory and Other Information from the CIDRA Database (Provided in Volumes 2 through 5)

Appendix C

The Inventory of Plutonium, Americium, and Uranium from the Rocky Flats Plant Buried at the Subsurface Disposal Area from 1954–1972

Appendix C

The Inventory of Plutonium, Americium, and Uranium from the Rocky Flats Plant Buried at the Subsurface Disposal Area from 1954–1972

J. J. Einerson
D. E. Kudera
T. H. Smith

INTRODUCTION

The Idaho National Engineering Laboratory (INEL) historical data task (HDT) was established to develop a detailed inventory of waste buried in the INEL Subsurface Disposal Area (SDA) from 1952 through 1983. The inventory will be used for performing a risk assessment under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) to help determine the most appropriate remedial action, if any, for the SDA.

Waste received from the Rocky Flats Plant (RFP) constitutes part of the SDA inventory and was buried in the SDA from 1954 to 1972. The last plutonium and americium from the RFP was buried in 1970; only uranium was buried in 1971 and 1972.

The plutonium, americium, and uranium quantities that have been estimated to be buried at the SDA historically came from a 1971 letter from Lee to Soule (Lee 1971); these estimates have been used in a variety of subsequent INEL documents. However, RFP personnel do not believe that these quantities represent the best estimates. Therefore, INEL personnel have concluded that inventories provided in Lee (1971) are not adequate for conducting the SDA risk assessment. The previous RFP inventory estimate was inadequate because waste analysis technology was limited in the early years of operation.

The numbers used for the RFP portion of the SDA inventory in the risk assessment should reflect the *best current thinking of both RFP and INEL personnel*. Therefore, the HDT addresses the question of the best estimates for the RFP shipments to the SDA.

A briefing for INEL personnel was conducted at the RFP on August 24, 1993. Based on information presented by RFP personnel at that briefing and on subsequent INEL calculations using that information, best estimates and upper bounds were developed for the amounts of plutonium, enriched uranium, and americium in the RFP waste buried at the SDA.

The results of those calculations are documented here. The details of the pertinent information received from the RFP and of the INEL calculations are not presented here. For perspective, a brief summary of available information on RFP waste buried in the SDA follows.

AVAILABILITY OF INFORMATION ON RFP WASTE

The existing primary sources of information at the INEL concerning 1954 through 1972 RFP waste are a letter from the Lee to Soule (Lee 1971) and miscellaneous shipping records. There are indications that these information sources are not accurate. One indication is that individual drums have been found at the INEL containing plutonium levels above those identified in the shipping documents. RFP personnel also have stated that plutonium quantities in INEL records are significantly lower than the actual amount.

The only officially recorded removals of plutonium from the processing stream at the RFP were through War Reserve scheduled shipments, approved special orders, and authorized measured discards. The removals by War Reserve schedule and special orders are quite accurate. The removals through measured discard were almost entirely in the form of solidified liquid waste.

The volume of the liquid waste was measured and the liquid was sampled and analyzed for its radionuclide content before solidification. Measuring and sampling these liquids was a difficult problem, and the RFP records show that the credit taken for measured discards has been inadequate. The fact that more plutonium was discarded in this waste than credit was taken for is substantiated by the fact that the sludges accumulated during waste treatment have shown a plutonium content of over twice the weight taken as measured discards.

Discard values or levels for solid waste shipped offsite were not established. Even if these levels had been established, it would have been difficult to determine the amount of accountable material because the only control was by measuring the gamma radiation level, which is not an accurate method for measuring plutonium, americium, and uranium in solid waste. In the early 1960s, extensive research and development work took place at the RFP to improve drum counting methods. The use of drum counters began in 1964. However, for the first few years, shipping personnel did not use the results of the drum counters because they mistrusted the results. In addition, no authorized measurement methods were available for boxes through the early 1970s. A Geiger-Müller (G-M) gamma survey was performed on the boxes to try to ensure that large amounts of radionuclides were not being shipped. Acceptable techniques for measuring the radionuclide content of boxes were not available at the RFP before 1978.

Because of the significant limitations in measuring plutonium in most of the RFP waste buried at the SDA, further analysis of the shipping records was not considered productive. INEL personnel have long been aware that RFP personnel have been seeking to improve their knowledge of the disposition of the plutonium since at least 1964, and that RFP personnel have reached some conclusions about the disposition of the plutonium.

The RFP approach to investigating the disposition was based on a plantwide plutonium balance. Table C-1 summarizes the results of this RFP investigation, which provides the best estimates and INEL-calculated upper bounds for the total amount of plutonium, Am-241, and enriched uranium that was shipped from the RFP to the INEL and buried in the SDA from 1954 through 1972. Table C-2 presents the annual best estimates of plutonium, Am-241, and enriched uranium shipped from the RFP to the INEL for burial.

Table C-1. Summary of best estimates and upper bounds of Rocky Flats Plant waste buried at the Subsurface Disposal Area.

Radionuclide	Best estimate (kg)	Upper bound (kg)
Plutonium	1,102	1,455
Am-241	44	58
Enriched uranium	386	603

Table C-2. Annual best estimates of plutonium, Am-241, and enriched uranium shipped to the Idaho National Engineering Laboratory and buried in the Subsurface Disposal Area from 1954 through 1972.

Year	Plutonium best estimates (kg)	Am-241 best estimates (kg)	Enriched uranium best estimates (kg)
1954	1.6	0.1	3.1
1955	8.0	0.3	8.2
1956	16.1	0.6	10.7
1957	23.3	0.9	21.9
1958	54.1	2.2	71.8
1959	59.4	2.4	8.8
			(6.4)
1960	70.3	2.8	94.1
1961	64.3	2.6	47.7
1962	83.7	3.3	55.4
1963	101.8	4.1	11.2
1964	87.3	3.5	51.5
1965	125.5	5.0	8.6
			(-13.1)
1966	153.2	6.1	2.8
			(-11.1)
1967	72.0	2.9	8.4
	(58.9)	(2.4)	
1968	68.1	2.7	1.3
	(25.5)	(1.0)	(-14.7)
1969	74.0	3.0	10.0
1970	94.2	3.8	31.8
			(23.5)
1971	None	None	0.7
1972	None	None	2.7
			(0.6)

NOTE: For plutonium and Am-241 for 1967 and 1968 and enriched uranium for 1959, 1965, 1966, 1968, 1970, and 1972, the numbers in parentheses are the annual quantities used for the cumulative best estimate. The top numbers are annual best estimates. The differences are assumed to be because of recovery of backlogged material or material from the cleanout of equipment.

SUMMARY

Table C-1 provides the best estimates and upper bounds for the amounts of plutonium (material type Pu-52),[a] Am-241, and enriched uranium (material type U-38)[b] shipped to the INEL from the RFP and buried in the SDA during the years 1954 through 1972.

Table C-2 provides the annual best estimates for the amounts of plutonium, Am-241, and enriched uranium shipped to the INEL from the RFP and buried in the SDA during the years 1954 through 1972. Plutonium and americium were not buried in the SDA after 1970.

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a. Material type Pu-52 is the U.S. Department of Energy (DOE) designation for plutonium whose radionuclide mixture is considered weapons grade. The mixture breakdown is 0.0001 Pu-238, 0.9389 Pu-239, 0.0575 Pu-240, 0.0034 Pu-241, and 0.0002 Pu-242 by mass (EG&G Idaho 1985).

b. Material type U-38 is the DOE designation for enriched uranium whose radionuclide mixture is 0.0093 U-234, 0.9308 U-235, 0.0034 U-236, and 0.0565 U-238 by mass (EG&G Idaho 1985).

REFERENCES FOR APPENDIX C

EG&G Idaho, (EG&G Idaho, Inc.) 1985, *Solid Waste Management Information System (SWIMS) Users Manual*, April 1985.

Lee, W. H., 1971, letter to H. F. Soule, "Rocky Flats Solid Waste Shipped to NRTS," June 10, 1971.

Appendix D

Detailed Evaluation of Inventory Entries for Contaminants with Unknown Quantities

Appendix D

Detailed Evaluation of Inventory Entries for Contaminants with Unknown Quantities

This appendix evaluates the inventory entries for nonradiological contaminants with unknown quantities. Resolution of the inventory entries for radiological contaminants with unknown entries is discussed in Section 4. This appendix also provides an estimate of the volumes of Rocky Flats Plant (RFP) waste streams.

Evaluation of Unknown Quantities of Nonradiological Contaminants

Table D-1 presents the detailed results for the evaluation of the unknown quantities of nonradiological contaminants. For each contaminant with one or more entries giving the quantity as unknown, the designator is given for all waste streams containing unknown quantities of the contaminant. Next is a discussion of the attempt to estimate an upper-limit quantity (or, in the case of the RFP waste, a best estimate). The last column of the table compiles the results for all unknown entries of that contaminant.

The results of the evaluation of the unknown quantities of contaminants are not incorporated into the Contaminant Inventory Database for Risk Assessment (CIDRA) database because of their lower reliability.

Estimate of the Volumes of RFO-DOW-1H to RFO-DOW-14H Waste Streams

The total volumes of the various RFP waste streams buried in the Subsurface Disposal Area (SDA) are unknown. The available information did not provide an estimate of the annual volume or total volume for RFP buried waste streams RFO-DOW-1H through RFO-DOW-14H. Lee (1971) provides a total volume of waste that was shipped from the RFP to the Radioactive Waste Management Complex (RWMC) each year from 1954 to 1970. There is no indication, however, of the volumes of each type of waste, (i.e., each waste stream). The volume of these waste streams may be important for some future calculations. Therefore, an estimate of these volumes is made here.

The extrapolations to calculate the radionuclides and hazardous constituents present in each of the first 14 waste streams were based mostly on available information on RFP stored waste (Clements 1982). Therefore, the estimate of the volumes was made using the number of drums and boxes of each applicable content code received from 1971 through 1981 from the Clements (1982) report on stored waste. It was assumed that each drum is a 55-gal drum and that each box is 4 × 4 × 7 ft. The numbers of drums and boxes and the total volume for each waste stream are shown in Table D-2. The relative volume percent of each waste stream was calculated from these numbers and is also shown in Table D-2. However, the total volume shipped from the RFP each year from Lee (1971) must be corrected for the amounts of organic sludge (RFO-DOW-15H) and evaporator salts (RFO-DOW-17H) that were buried. This total yearly volume (1954 through 1970) correction is shown in Table D-3. The corrected total yearly volumes are then multiplied by the volume percents for each waste stream (Table D-2) to obtain the annual volume of each of the first 14 buried waste streams for the years 1954 through 1970. These estimates are shown in Table D-4.

Table D-1. Results of the search to estimate upper-limit[a] quantities for nonradiological contaminants whose quantities are listed as unknown.

Contaminant	Streams where listed	Evaluation of possible upper-limit[a] quantity for each stream	Source(s) of information	Reasonable upper limit[a] on total unknown quantity over all streams shown
1,4-bis(5-phenyloxazol-2-yl)benzene	OFF-WSU-1H	Most of the waste in the 2.15-m^3 stream is paper, glassware, animal carcasses, and aqueous and organic solutions. The contaminant is believed to be <10% of the stream. Thus, an upper limit on the quantity of the contaminant would be 0.22 m^3, or about 2.0E+05 g, at a specific gravity of about 0.9.	Detailed data form; Clements (1980)	An upper-limit estimate is 2.0E+05 g
3-methyl-cholanthrene	OFF-UOW-1H	Most of the waste in the 12.97-m^3 stream is paper, laboratory clothing, glassware, and animal carcasses. Small amounts of various laboratory chemicals are included. The contaminant is believed to be a small fraction (<1%) of the stream. Thus, an upper limit on the quantity of the contaminant would be 0.13 m^3, or about E+05 g.	Detailed data form; Clements (1980)	An upper-limit estimate is E+05 g
Alcohols (assumed to be ethyl alcohol)	RFO-DOW-2H	See the evaluation of Versenes.	Clements (1982)	
Asbestos	ANL-765-1H	The detailed data form contains no information useful for estimating the quantity of asbestos other than the total stream volume of 1,815 m^3.	Detailed data form	A best estimate is 2.3E+06 g
	ANL-EBRI-1H	The detailed data form indicates that 511 ft^3 of asbestos was contained in the waste for September 1959. The quantities of asbestos during the remaining 5 years in which this stream was generated are not stated. Thus, all that is known is a lower limit of 511 ft^3 × 16 lb/ft^3 × 0.15 asbestos contents × 454 g/lb = 5.6E+05 g asbestos.	Detailed data form	
	D&D-OMR-1H	Only an inexact estimate can be made. The reference report states that the volume of metallic waste is 40,000 ft^3 (the external volume of the containers in which the waste was shipped). Photos suggest that about one-fourth of this volume is piping (the remainder being one-half tanks and one-fourth heat exchangers, pumps, etc.) If one-third of the piping is insulated, the *container* volume for such waste was about 40,000/12 = 3,300 ft^3, or 26 4 × 4 × 8-ft boxes. If there are 10 8-ft segments of insulated piping in each box, the total length would be 80 × 26 ft = 2,080 ft. Based on an estimate for TRA pipe insulation, assume the insulation volume is 1/3 × 2,080 ft = 700 ft^3. Based on assumptions used for the known quantity of asbestos in stream TRA-603-10H, assume 700 ft^3 × 16 lb/ft^3 × 0.15 asbestos (remainder of insulation material was magnesia and hydrated magnesium carbonate) × 454 g/lb = 7.6E+05 g asbestos.	Detailed data form; Hine (1980)	

Table D-1. (continued).

Contaminant	Streams where listed	Evaluation of possible upper-limit[a] quantity for each stream	Source(s) of information	Reasonable upper limit[a] on total unknown quantity over all streams shown
Asbestos (continued)	D&D-SPT-1H	The reference report indicates 18 m^3 of waste containers of piping. However, the photos suggest that little insulation is present. Assume the quantity of asbestos is small compared with that in other streams (<E+05 g).	Detailed data form; Smith (1979)	
	D&D-TAN-1H	The waste from two TAN D&D tasks is in this stream. The reference report for the TAN PM-2A task mentions asbestos only in connection with a 289-ft^3 tank. Very little piping is involved. Assuming cubical tank dimensions, 2-in. insulation thickness, and other assumptions as in stream D&D-OMR-1H, 6 sides × 6.6 ft × 6.6 ft × 1/6-ft-thick × 16 lb/ft^3 × 0.15 asbestos × 454 g/lb = 4.8E+04 g asbestos. The other D&D task (TAN/TSF-3 pad) involved no asbestos.	Detailed data form; Smith (1983) and Smith and Wisler (1984)	
	NRF-617-2H	This stream composites all of the lead and asbestos from NRF from 1955 through 1983. The volume of the stream is unknown, and the volumes of the two contaminants are unknown. There is no way to estimate reasonable upper limits for the quantities of lead and asbestos. The quantities could be large.	Detailed data form	
	OFF-LRL-1H	The reference report mentions asbestos only in connection with the Lawrence Berkeley Laboratory portion (263 m^3) of the stream. The asbestos millboard that is mentioned is assumed here to be a small fraction (1%) of the volume of the highly mixed waste stream. Assuming that the board has a density of 80 lb/ft^3 and is 25% asbestos, the mass of asbestos of 0.01 × 263 m^3 × 35.31 × 80 × 0.25 × 454 = 8.4E+05 g asbestos.	Detailed data form; Clements (1980)	
	OFF-LRL-2H	See discussion for stream OFF-LRL-1H. Stream OFF-LRL-2H is from Lawrence Livermore Laboratory. The reference does not mention asbestos in waste shipments from Lawrence Livermore. For simplicity, the data forms for the two shipments listed identical contaminants for the unknowns.	Detailed data form; Clements (1980)	
Benzene	OFF-UOW-1H	Most of the waste in the 12.97-m^3 stream is paper, laboratory clothing, glassware, and animal carcasses. Small amounts of various laboratory chemicals are included. The contaminant is believed to be a small fraction (<1%) of the stream. Thus, an upper limit on the quantity of the contaminant would be 0.13 m^3, or 1.2E+05 g at a specific gravity of 0.9.	Detailed data form; Clements (1980)	An upper-limit estimate is 1.2E+05 g

Table D-1. (continued).

Contaminant	Streams where listed	Evaluation of possible upper-limit[a] quantity for each stream	Source(s) of information	Reasonable upper limit[a] on total unknown quantity over all streams shown
Beryllium	CFA-639-1H	The detailed data form states that the stream is 7 m^3 of paper, wood, and metal scrap with some beryllium, in two wooden boxes. Based on the varied composition of the waste, the quantity of beryllium is estimated to be very small compared with that in other streams (<<E+06 g).	Detailed data form	An upper-limit estimate for beryllium and beryllium oxide is a total of 8.0E+06 g
	CFA-654-1H	The detailed data form states that the stream includes scrap metals (steel, lead, beryllium, zirconium), sludge, and combustibles. The total volume is 50 m^3. The amount of lead is 800 lb. Based on the varied composition of the waste, the quantity of beryllium is estimated to be very small compared with that in other streams (<<E+06 g).	Detailed data form	
	OFF-ATI-1H	The reference report mentions 19 55-gal drums containing beryllium or beryllium oxide, as well as a plutonium-beryllium neutron source. Other waste is also contaminated with beryllium. A rough estimate, believed to be conservative, is developed by assuming that the 19 drums contained only beryllium scrap, and then doubling the result to allow for beryllium in other containers. The weights of waste containers received at the RWMC that are packed with metal scrap do not correspond to 100% dense packing of the metal, but rather range from 10% to 20% of theoretical density. Conservatively assuming 30% of theoretical density leads to a beryllium mass of 19 drums $\times$ 7.4 ft^3/drum $\times$ 0.3 $\times$ 115 lb/ft^3 $\times$ 454 g/lb = 2.2E+06 g. Doubling this amount gives 4.4 E+06 g.	Detailed data form; Clements (1980)	
	RFO-DOW-15H	Beryllium was machined and made into shapes at the RFP. Machining and/or degreasing solvents used in beryllium operations could have been included in this organic sludge stream. There is no indication of the amounts of beryllium-contaminated organics (or the concentrations of beryllium) included in this stream. The only current information is from the cited report, which states that degreasing solvents generated by Building 444 operations are contaminated with beryllium. It is assumed here that the beryllium is 10% of the amount of the plutonium. The total amount of plutonium disposed of in this stream is 2.9 kg. Thus, the beryllium is estimated to be 2.9E+02 g.	Clements (1982)	

Table D-1. (continued).

Contaminant	Streams where listed	Evaluation of possible upper-limit[a] quantity for each stream	Source(s) of information	Reasonable upper limit[a] on total unknown quantity over all streams shown
Beryllium (continued)	TAN-607-3H	The detailed data form contains no information useful for estimating the quantity of beryllium. The volume of the waste stream is 653 m^3. The quantity of beryllium would be a small fraction of that volume, but the fraction is unknown.	Detailed data form	
	TAN-633-2H	The detailed data form contains no information useful for estimating the quantity of beryllium. The volume of the waste stream is unknown. The quantity of beryllium is expected to be much smaller than that in other streams because this stream consists of metallurgical samples and test specimens.	Detailed data form	
	TAN-640-1	The beryllium in this stream was present as part of a radium-beryllium radiation source. The activity of the source was 1 Ci of Ra-226, so the mass of Ra-226 was approximately 1 g. The mass of beryllium was probably less than E+02 g.	Detailed data form	
	PDA-RFO-1A	The beryllium foundry operation generated Be and BeO contaminated wastes in the form of paperwipes, plastic, graphite molds and crucibles, small tools, and casting sculls (casting residue). It was estimated by foundry personnel that the casting process alone would generate 20 to 20 lb/day of Be and BeO sculls. The overall average production rate was estimated at 125 day/yr. Thus, the estimated average rate of sculls generated each year would be 2,500 to 3,750 lb. The sculls may be in solid (Be metal) or powder (BeO) forms. In addition to sculls, impure or damaged castings that could not be salvaged were periodically included with other foundry wastes. A beryllium casting may weigh up to 125 lb. Between September 1972 and April 1978, depleted uranium and beryllium wastes were placed on Pad A. At 3,750 lb/yr for approximately 5.5 years, it is estimated that this unknown quantity on Pad A could be 1.7E+06 grams of beryllium, as the metal or the oxide.	Clements (1985)	
Beryllium oxide	OFF-ATI-1H	See above entry for beryllium in stream OFF-ATI-1H.	Detailed data form; Clements (1980)	

Table D-1. (continued).

Contaminant	Streams where listed	Evaluation of possible upper-limit[a] quantity for each stream	Source(s) of information	Reasonable upper limit[a] on total unknown quantity over all streams shown
Beryllium oxide (continued)	RFO-DOW-3H	It has been stated that the first-stage sludge may contain low concentrations of beryllium. Samples of combined first- and second-stage sludges (after 1979) may contain up to 1,000 ppm of beryllium. Because this sludge was formed by precipitation with caustic, it is assumed that the beryllium would be present as the oxide. It is assumed that the mass of a filled drum is about 400 lb. Assume that 700 drums/yr contained 1,000 ppm beryllium. Multiplying 1,000 ppm × 350 lb/drum × 700 drums × 17 yr × 454 g/lb = about 1.9E+06 g of beryllium oxide.	Clements (1981) and Clements (1982)	
	TAN-607-2H	The detailed data form contains no information useful for estimating the quantity of beryllium oxide. The volume of the waste stream is unknown.	Detailed data form	
Cadmium	ANL-752-3H	The detailed data form contains no information useful for estimating the quantity of cadmium, other than the total stream volume of 23.1 m^3 and the fact that much of the volume was concrete used to stabilize the evaporator bottoms.	Detailed data form	There is no information to support an upper-limit estimate
Carbon tetrachloride	OFF-UOW-1H	Most of the waste in the 12.97-m^3 stream is paper, laboratory clothing, glassware, and animal carcasses. Small amounts of various laboratory chemicals are included. The contaminant is believed to be a small fraction (<1%) of the stream. Thus, an upper limit on the quantity of the contaminant would be 0.13 m^3, or 2.0E+05 g at a specific gravity of 1.6.	Detailed data form; Clements (1980)	An upper-limit estimate is 2.0E+05 g
Chloroform	None identified	Chloroform was not identified in any RFP waste streams and is, therefore, not listed as an unknown in any RFP stream. However, it has been detected frequently in environmental monitoring at the RWMC and was used at the RFP. If chloroform were present in large quantities in RFP waste, it would have been discarded as part of the organic sludge waste stream because it is an organic compound. Uses of chloroform at the RFP included analyses of the gallium content of plutonium samples, as a glue used by carpenters to join plexiglas, and for dissolving plastics. The first date of use of chloroform at the RFP has not been identified. An estimate is as follows. A 1974 harmful materials inventory indicated a chloroform inventory of	ChemRisk (1992a) and ChemRisk (1992b)	A best estimate is E+07 g

Table D-1. (continued).

Contaminant	Streams where listed	Evaluation of possible upper-limit[a] quantity for each stream	Source(s) of information	Reasonable upper limit[a] on total unknown quantity over all streams shown
Chloroform (continued)		5,513 L (8.9 tons). It has been conservatively estimated in ChemRisk (1992a) that the airborne emissions of chloroform from the RFP were 1.5 to 15 tons/yr from 1952–1974. The report estimated an airborne emission rate of methylene chloride (used for stripping paint) of 5 to 15 tons/yr from 1952-1954. Because the two compounds are similar chemically and were not used in major plant processes, and the airborne emission rates have been estimated to be similar, it will be assumed that the total amount of RFP chloroform buried is the same as the amount of methylene chloride buried, about E+07 g.		
Chromium	ANL-752-3H	The detailed data form contains no information useful for estimating the quantity of chromium, other than the total stream volume of 23.1 m^3 and the fact that much of the volume was concrete used to stabilize the evaporator bottoms.	Detailed data form	There is no information to support an upper-limit estimate
	TAN-633-4H	The chromium was present in the form of an unknown amount of nichrome cladding and structural material. The amount cannot be estimated, but it is expected to be small because this stream consists of metallurgical samples and test specimens.	Detailed data form	
Copper	D&D-TAN-1H	The indications are that copper was present in the waste only in the form of copper wiring. One 128-ft^3 box of waste contained galvanized steel, copper, and rubber. A reasonable upper limit is 100 lb (4.5E+04 g) of copper, but this number is highly speculative. The uncertainty is perhaps an order of magnitude in both directions.	Detailed data form; Smith (1980), Smith and Hine (1982), and Smith (1983)	An upper-limit estimate is 4.5E+04 g. Copper is likely present in other general waste streams, in the form of copper wiring or copper tubing. There is no information to support an estimate of the quantity in the other streams.
Cyanide	CFA-684-1H	One entry is for sodium cyanide and is 936 g. The other entry is an unknown quantity of liquid cyanide (cation unknown) sorbed on vermiculite in a 5-gal container. As a conservative estimate, assume that the 5-gal container holds a concentrated cyanide solution (10% by volume). The amount would be on the order of 0.5 gal, or 2 L × 1,000 g/L = 2,000 g. The total of the two entries is 2.9E+03 g.	Detailed data form	An upper-limit estimate is 2.9E+03 g

Table D-1. (continued).

Contaminant	Streams where listed	Evaluation of possible upper-limit[a] quantity for each stream	Source(s) of information	Reasonable upper limit[a] on total unknown quantity over all streams shown
Dibutylethylcarbutol	RFO-DOW-15H	It has been reported that enriched uranium recovery included a solvent extraction process that used dibutylethylcarbutol and dodecane. It is expected that these organic compounds would have been disposed of in this waste stream. No information is available on dibutylethylcarbutol quantities at the RFP. No way to provide a realistic estimate of the total quantity is apparent at present. A rough estimate was developed as follows. Assume that the dibutylethylcarbutol was mixed with dodecane or kerosene, and disposed of as part of the "other organic" constituents in this stream (57,493 gal buried). These "other organics" consist of 1,1,1-trichloroethane, trichloroethylene, tetrachloroethylene, and used oils. The dibutylethylcarbutol and kerosene would have been part of the used oils. Assume that 10% of the volume of "other organics" (5,749 gal) contained dibutylethylcarbutol and that 25% of this volume was dibutylethylcarbutol. Assume that the density is 1 g/mL. Thus, there is 1,437 gal × 3,785 mL/gal × 1 g/mL = 5.4E+06 g.	ChemRisk (1992b) and Kudera (1987)	A best estimate is 5.4E+06 g
	RFO-DOW-18H	As discussed under stream RFO-DOW-15H, the enriched uranium recovery included a solvent extraction process that used dibutylethylcarbutol and dodecane. It is expected that these organic compounds would have been disposed of primarily in waste stream RFO-DOW-15H. Traces of dibutylethylcarbutol may have remained in the enriched uranium of stream	ChemRisk (1992a) and Kudera (1987)	
	RFO-DOW-18H	RFO-DOW-18H, but the quantities would be negligible compared with the portion that went into stream RFO-DOW-15H.		
Diisopropylfluoro-phosphate	OFF-UOW-1H	This contaminant was used at the generator in laboratory experiments on animals. The quantity in the waste is unknown, but it is believed to be a very small fraction (<<1%) of the 12.97 m^3 of highly varied waste in the stream. Thus, the quantity of the contaminant would be <<0.1 m^3, and <<E+05 g.	Detailed data form; Clements (1980)	The quantity is unknown, but is believed to be <<E+05 g
Ether	TAN-607-3H	The detailed data form contains no information useful for estimating the quantity of ether. The volume of the waste stream is 653 m^3. The quantity of ether would be a small fraction of that volume, but the fraction is unknown.	Detailed data form	There is no information to support an upper-limit estimate

Table D-1. (continued).

Contaminant	Streams where listed	Evaluation of possible upper-limit[a] quantity for each stream	Source(s) of information	Reasonable upper limit[a] on total unknown quantity over all streams shown
Ethyl alcohol	OFF-WSU-1H	Most of the waste in the 2.15-m^3 stream is paper, glassware, animal carcasses, and aqueous solutions. The contaminant is believed to be <10% of the stream. Thus, an upper limit on the quantity of the contaminant would be 0.22 m^3, or 1.8E+05 g at a specific gravity of 0.8.	Detailed data form; Clements (1980)	A best estimate is 7.1E+07 g; see the evaluation of Versenes
Hydrofluoric acid	NRF-618-1H	This stream consists of dissolved fuel rods (assumed to be dissolved in hydrofluoric acid), which were sorbed on vermiculite and placed in poly bottles. The stream volume (container volume) is 5.5 m^3. If the contents of the bottles were 80% of the waste container volume and the volume of hydrofluoric acid was 50% of the bottle volume, then the hydrofluoric acid volume is roughly 2.2 m^3. At a specific gravity of 1.0, the hydrofluoric acid mass is approximately 2.2E+06 g.	Detailed data form	An upper-limit estimate is 2.2E+06 g
Lead	ALE-ALE-1H	The volume of the stream is 3,544 m^3. One-half is D&D waste; the remainder is laboratory waste, filters, and miscellaneous items. The stream contains a very wide range of scrap materials: building rubble, electrical wiring, machinery, piping, heat exchangers, rags, metal turnings, glassware, filters, radiography sources, etc. The radiography sources are mentioned in connection with a substream from one laboratory building that contributed 5% of the waste. Lead was probably used to shield the sources. However, there is no basis for a reasonable upper-limit estimate on the amount of lead in this large-volume stream.	Detailed data form; Kee (1982)	Of the 13 streams with unknown quantities of lead, upper limits can be estimated for 4 streams totaling 2.0 E+07 g. The lead in two additional streams (CFA-633-1H and OFF-ATI-1H) is believed to be very small by comparison (e.g., <E+05 g), if present at all. For the seven remaining streams, no estimate can be developed. The waste records for those streams mention no items likely to contain lead in amounts approaching that of the massive reactor shield in OFF-SAM-2H. However, the cumulative amount of lead from NRF, in stream NRF-617-2H, could be considerable.
	ANL-765-2H	The detailed data form contains no useful information for estimating the quantity of lead, other than the total stream volume of 12.32 m^3.	Detailed data form	
	ANL-785-1H	The detailed data form contains no useful information for estimating the quantity of lead, other than the total stream volume of 77.79 m^3.	Detailed data form	

Table D-1. (continued).

Contaminant	Streams where listed	Evaluation of possible upper-limit[a] quantity for each stream	Source(s) of information	Reasonable upper limit[a] on total unknown quantity over all streams shown
Lead (continued)	CFA-633-1H	The volume of the stream is 14 m^3. The stream contains many types of scrap materials, mostly combustibles. The data form suggests that lead is a very minor constituent. Assume that the amount of lead is very small compared with the amount in other unknown streams (e.g., <E+05 g).	Detailed data form	
	CFA-638-1H	This stream consists of two small shielded casks, with a total volume of 0.2265 m^3. Each cask is about one-half the size of a 55-gal drum. The data gatherer assumed that the shielding was lead. The contents are two sealed sources, with 1 mCi total of Co-60. The source capsules are likely quite small. As a reasonable upper limit, assume that the lead lining is 1 in. thick and that the total drum surface area is 2 drums $\times$ [(.785 $\times$ 4 ft^2 $\times$ 2 ends) + (3.14 $\times$ 2 ft $\times$ 1.5 ft)] = 31 ft^2. The volume is 2.6 ft^3, or 0.074 m^3, approximately one-third of the volume of the casks. The mass of lead is 2.6 ft^3 $\times$ 687 lb/ft^3 = 1,786 lb = 8.1E+05 g, a near-upper limit on what the casks could accommodate structurally.	Detailed data form	
	NRF-617-2H	This stream composites all of the lead and asbestos from NRF from 1955 through 1983. The volume of the stream is unknown, and the volumes of the two contaminants are unknown. There is no way to estimate reasonable upper limits for the quantities of lead and asbestos. The quantities could be large.	Detailed data form	
	OFF-ATI-1H	The detailed data form indicates that, although lead is a waste from the generator's processes, lead is not believed to be present in the INEL waste shipments or, if present, it is present in extremely small quantities. The total stream volume is 1,390 m^3. The stream is mostly metal scrap and some test fuels. Assume that the amount of lead is very small compared with the amount in other unknown streams (e.g., <E+05 g).	Detailed data form	

Table D-1. (continued).

Contaminant	Streams where listed	Evaluation of possible upper-limit[a] quantity for each stream	Source(s) of information	Reasonable upper limit[a] on total unknown quantity over all streams shown
Lead (continued)	OFF-LRL-1H	Six drums had 5.1-cm lead lining, plus there were a few lead bricks. Assume that the 5.1-cm (2-in.)-thick lining covers the total drum surface area of 6 drums × [(.785 × 4 ft^2 × 2 ends) + (3.14 × 2 ft × 3 ft)] = 151 ft^2. The lead volume is 25 ft^3, or 0.71 m^3. Assume 5 bricks per drum @ 10 cm × 20 cm × 5 cm for 6 drums = 0.03 m^3. The total is 0.73 m^3. This volume is conservatively very high because each drum would weigh 0.74 m^3 × 35.31 ft^3/m^3 × 687 lb/ft^3/6 drums = 2,990 lb, well beyond the structural limit of a drum. The total mass of lead = 2,990 lb × 6 × 454 = 8.1E+06 g.	Detailed data form	
	OFF-LRL-2H	The estimate above for stream OFF-LRL-2H includes the lead in this stream, also.	Detailed data form	
	OFF-SAM-2H	The lead is in a stainless steel, aluminum, and lead reactor shield weighing 36,000 lb (volume stated as 47.3 m^3). Shield dimensions are 2.9 × 4.9 × 3.4 m. If the lead is 1/2 in. (0.013 m) thick × 81 m^2 in area, extending around the complete periphery, the total lead volume is 1.05 m^3. (NOTE: The 81 m^2 was arrived at by multiplying combinations of the dimensions of the shield: 2 [(2.9)(4.9) + (4.9)(3.4) + (3.4)(2.9)]. At a density of 687 lb/ft^3, the mass would be approximately 25,000 lb (1.1E+07 g), about two-thirds of the total mass of the shield. This is a reasonable fraction, so these assumptions are used here. Total radioactivity in the shipment is 0.4 Ci, so it is unlikely that other lead shielding was present.	Detailed data form; (Clements 1980)	
	TAN-607-3H	The detailed data form contains no useful information for estimating the quantity of lead, other than the total stream volume of 7,208 m^3 and the fact that a multitude of waste types are included.	Detailed data form	
	TAN-607-4H	The detailed data form contains no information useful for estimating the quantity of lead. The volume of the waste stream is 255 m^3. The quantity of lead would be a small fraction of that volume, but the fraction is unknown.	Detailed data form	
	TAN-607-5H	The detailed data form contains no information useful for estimating the quantity of lead. The volume of the waste stream is 7,208 m^3. The quantity of lead would be a small fraction of that volume, but the fraction is unknown.	Detailed data form	

Table D-1. (continued).

Contaminant	Streams where listed	Evaluation of possible upper-limit[a] quantity for each stream	Source(s) of information	Reasonable upper limit[a] on total unknown quantity over all streams shown
Lithium hydride	OFF-ATI-1H	A disassembled solid lithium hydride reactor shield may have been included in the waste shipped to the SDA, or it may have been shipped elsewhere.	Detailed data form; Clements (1980)	There is no firm evidence that the lithium hydride reactor shield was sent to the SDA. Therefore, no upper-limit estimate of the quantity of lithium hydride is made here.
Lithium oxide	RFO-DOW-3H	It has been stated that the second-stage sludge may contain lithium batteries. No other information on this subject is available. Lithium metal was used as the anode in commercially available alkaline batteries before 1970. The lithium in a discharged alkaline battery would be present as lithium oxide. No basis is currently available for estimating the quantity of lithium oxide. A search of RFP purchasing records for the time period might be helpful, but there is no way to reliably estimate how many of the purchased batteries are in the second-stage sludge. The amount is simply unknown, believed to be trace quantities.	Detailed data form	There is no information to support an estimate
Magnesium	OFF-NMR-1H	The reference report indicates that the amount of magnesium was small-to-trace quantities. Magnesium was added as an amendment for soil in which studies of plant uptake of radionuclides were performed. The waste soil was placed in 13 drums. A reasonable upper limit is believed to be less than 1 kg per drum, or about E+04 g for the stream. The physical form was probably a compound commonly used in fertilizers.	Detailed data form; Clements (1980)	A best estimate is 2.8E+05 g of magnesium
	OFF-SAM-2H	One 55-gal drum contains shavings of magnesium alloyed with 3% thorium and 1% zinc. It is assumed that no other waste is in the drum and that the drum is relatively heavy, weighing 600 lb. The upper limit on the quantity of magnesium would then be approximately 2.7E+05 g.	Detailed data form; Clements (1980)	

Table D-1. (continued).

Contaminant	Streams where listed	Evaluation of possible upper-limit[a] quantity for each stream	Source(s) of information	Reasonable upper limit[a] on total unknown quantity over all streams shown
Magnesium oxide	RFO-DOW-3H	This waste stream was produced by precipitation of the hydrated oxides of plutonium and americium from basic aqueous waste. Ferric sulfate, calcium chloride, magnesium sulfate, and flocculating agents were added to the solution to increase the efficiency of precipitating the very small amounts of radionuclides. The sludge that is produced consists mainly of the hydrated oxides of these compounds and 50 to 70 wt.% water. There is no magnesium metal in this waste stream. Assume that the stream consisted of 750 drums per year for 17 years (from 1954 through 1970). Assume a filled container weighs 500 lb, of which the tare weight is 70 lb. The waste, which weighs 430 lb, contains 50 lb of cement; 50% of the remaining sludge is water. Thus, the sludge without the water weighs 190 lb and contains the oxides of iron, calcium, magnesium, and the flocculating agents. Assume 25% of the dry sludge is MgO, or 47.5 lb/drum. 47.5 lb/drum × 454 g/lb × 750 drums/yr × 17 yr = 2.8E+08 g of magnesium oxide.	Clements (1982)	A best estimate is 2.8E+08 g of magnesium oxide
Manganese	OFF-NMR-1H	The reference report indicates that the amount of manganese was small-to-trace quantities. Manganese was added as an amendment for soil in which studies of plant uptake of radionuclides were performed. The waste soil was placed in 13 drums. A reasonable upper limit is believed to be less than 1 kg per drum, or about E+04 g for the stream. The physical form was probably a compound commonly used in fertilizers.	Detailed data form; Clements (1980)	An upper-limit estimate is E+04 g
Mercury	CFA-610-1H	One shipment contained 2 ft^3 of mercury batteries in a cardboard box. The mercury in a battery is estimated at 30% by volume (1% as mercury and the remainder as mercuric oxide), per material safety data sheets for mercury batteries. If the batteries were packed in the box with a volumetric efficiency of 80%, an upper-limit amount of mercury would be roughly 0.48 ft^3. However, considering the weight of the mercury results in a lower estimate: assume the maximum weight of the filled cardboard box is 100 lb. At a density of 695 lb/ft^3 for HgO, the box could hold only 0.14 ft^3 of HgO, even if the weight of all other battery constituents were ignored. The mass would be 0.14 ft^3 × 695 lb/ft^3 × 454 g/lb = 4.4E+04 g. Another shipment contained 30 ft^3 of mud contaminated with mercury. Hot spots from INEL mercury spills have been as high as 80,000 ppm. Assuming 10% of the mud contained mercury at 80,000 ppm and the	Detailed data form; material safety data sheets	An upper-limit estimate is 1.2E+06 g

Table D-1. (continued).

Contaminant	Streams where listed	Evaluation of possible upper-limit[a] quantity for each stream	Source(s) of information	Reasonable upper limit[a] on total unknown quantity over all streams shown
Mercury (continued)	CFA-610-1H	remaining 90% was relatively clean (10 ppm), the average concentration would be about 8,000 ppm. The amount of mercury would be 0.24 ft^3. Assuming liquid mercury, the mass would be 0.24 ft^3 × 846 lb/ft^3 × 454 g/lb = 9.2E+04 g. The total for the two shipments is about 1.4E+05 g.		
	OFF-ATI-1H	The detailed data form indicates that the quantity of mercury is "negligible" if present at all. The cited reference indicates mercury present as small quantities in plastic bottles. The total volume of the waste stream is 1,390 m^3. Assume that the amount of mercury is small compared with the amount in other unknown streams (e.g., <E+05 g).	Detailed data form; Clements (1980)	
	RFO-DOW-3H	Mercury metal was used at the RFP mostly in instruments such as barometers and thermometers, plant machinery, mercury switches, and experimental apparatus. Mercury was collected from plant sources and purified by distillation at the plant. It was recycled back to the originating area in 5-lb containers. There were no large sources of mercury at the RFP. The second-stage sludges (RFP Content Code 002) may contain mercury batteries and small amounts of mercury in pint bottles. Assume that about 100 lb (4.5E+04 g) of mercury annually, or 7.7E+05 g total during 17 years, were disposed of in this waste stream. Assume that the amount of mercury in the mercury alkaline batteries that may have been discarded in this stream is negligible by comparison.	ChemRisk (1992b) and Clements (1982)	
	TAN-607-3H	The detailed data form contains no information useful for estimating the quantity of mercury.	Detailed data form	
	TAN-607-5H	The detailed data form indicates that within a 120-ft^3 container was canned mud containing mercury. Assume that the mud filled the container up to the weight limit of about 10,000 lb. Also, assume that the mud contained mercury at an average concentration of 8,000 ppm (as developed above for stream CFA-610-1H). Assuming liquid mercury at 846 lb/ft^3 and mud at 120 lb/ft^3, the density of mud-mercury mixture would be about 126 lb/ft^3. The weight limit of 10,000 lb would be reached with 79 ft^3 of the mixture. The weight of mercury would be 79 ft^3 × 0.008 × 846 lb/ft^3 × 454 g/lb = 2.4E+05 g.	Detailed data form; interview with INEL Waste Area Group-1 manager	

Table D-1. (continued).

Contaminant	Streams where listed	Evaluation of possible upper-limit[a] quantity for each stream	Source(s) of information	Reasonable upper limit[a] on total unknown quantity over all streams shown
Methyl alcohol	OFF-UOW-1H	Most of the waste in the 12.97-m^3 stream is paper, laboratory clothing, glassware, and animal carcasses. Small amounts of various laboratory chemicals are included. The contaminant is believed to be a small fraction (<1%) of the stream. Thus, an upper limit on the quantity of the contaminant would be 0.13 m^3, or 1.0E+05 g, at a specific gravity of 0.8.	Detailed data form; Clements (1980)	An upper-limit estimate is 2.8E+05 g; see the evaluation of Versenes
	OFF-WSU-1H	Most of the waste in the 2.15-m^3 stream is paper, glassware, animal carcasses, and aqueous solutions. The contaminant is believed to be <10% of the stream. Thus, an upper limit on the quantity of the contaminant would be 0.22 m^3, or 1.8E+05 g, at a specific gravity of 0.8.	Detailed data form; Clements (1980)	
Nickel	TAN-633-4H	The nickel was present in the form of an unknown amount of nichrome cladding and structural material. The amount cannot be estimated, but is expected to be small because this stream consists of metallurgical samples and test specimens.	Detailed data form	There is no information to support an upper-limit estimate.
Nitric acid	OFF-GEC-1H	A small fraction of this highly varied 7-m^3 stream is nitric acid. However, the nitric acid was neutralized before placement in containers filled with cement. A reasonable upper limit is believed to be 0.7 m^3 of nitric acid, although all of the acid may have been neutralized. At a specific gravity of 1.5, the upper limit mass would be $0.7 \times 1.5 \times 10^6$ = 1.1E+06 g.	Detailed data form; Clements (1980)	An upper-limit estimate is 2.3E+06 g
	OFF-UNR-1H	The nitric acid may or may not have been shipped to the SDA. The shipment totaled 8.04 m^3 of miscellaneous laboratory waste and radioactive sources. Nitric acid is believed to have been a minor constituent. Any nitric acid would have been in 1-L bottles. A reasonable upper limit is hypothesized as 10% of the shipment volume, or 0.8 m^3. At a specific gravity of 1.5, the upper-limit estimate is $0.8 \times 1.5 \times 10^6$ = 1.2E+06.	Detailed data form; Clements (1980)	
	RFO-DOW-4H	Nitric acid was used in large volumes at the RFP. However, any nitric acid in liquid form in the waste was made basic to precipitate the radionuclides. Nitric acid was also absorbed by rags and filters, and may have been present as a film on metal equipment. Thus, no substantial amount of nitric acid is expected to be present in the RFP waste streams. However, contact of nitric acid with cellulosic materials such as rags could have formed nitrocellulose. See the separate discussion under the entry for nitrocellulose.	Detailed data form	

Table D-1. (continued).

Contaminant	Streams where listed	Evaluation of possible upper-limit[a] quantity for each stream	Source(s) of information	Reasonable upper limit[a] on total unknown quantity over all streams shown
Nitric acid (continued)	RFO-DOW-6H	Filters in the exhaust system of the gloveboxes could have contained some condensed nitric acid. However, the waste was normally dry when it was packaged. If the waste was damp, some absorbent material was added to the waste. The filters were made out of asbestos, which is a naturally occurring mineral silicate fiber. Therefore, only trace amounts of nitric acid could have been in the filters, and no cellulose was present to form any nitrocellulose. It is estimated that no nitrocellulose is present in this waste stream.	Clements (1982)	
Nitrobenzene	RFO-DOW-15H	It has been reported that this waste stream contains trace quantities of organic laboratory waste such as nitrobenzene. No information is available on nitrobenzene quantities used in RFP operations. No method is currently apparent to provide a realistic estimate of the total quantity of nitrobenzene in this stream. Therefore, the quantity is left as "unknown—trace."	Clements (1982)	No information is available to support a best estimate. The quantity is "unknown—trace."
Nitrocellulose	RFO-DOW-4H	Some of the rags in the "Paper and Rags—Moist" category (RFP Content Code 336) were used to clean up liquid nitric acid from inside gloveboxes. Before 1970, most of these moist rags containing nitric acid were disposed of without removal of the nitric acid. The chemical reaction between the nitric acid and the rag would form nitrocellulose. No information is available on the quantity of rags used to clean up nitric acid. However, because this waste stream also contains plastics, overalls, surgeon's gloves, cardboard, wood, etc., it is estimated that 10% of this waste stream was rags and 10% of the rags contained nitric acid. Assume that all of this waste was in 55-gal drums and that each drum contained 125 lb of waste. Assume that 700 drums of this waste were disposed of annually for 17 years (1954 to 1970). The assumption of 1% of the waste being present as nitric acid/rags would give the following estimate: 0.01 × 125 lb × 454 g/lb × 700 drums/yr × 17 yr = 6.8E+06 g of nitrocellulose if total reaction occurred.	Detailed data form; Clements (1982)	A best estimate is 6.8E+06 g
	RFO-DOW-6H	Filters in the exhaust system of the gloveboxes could have contained some condensed nitric acid. However, the waste was normally dry when it was packaged. If the waste was damp, some absorbent material was added to the waste. The filters were made out of asbestos, which is a naturally occurring	Clements (1982)	

Table D-1. (continued).

Contaminant	Streams where listed	Evaluation of possible upper-limit[a] quantity for each stream	Source(s) of information	Reasonable upper limit[a] on total unknown quantity over all streams shown
Nitrocellulose (continued)	RFO-DOW-6H	mineral silicate fiber. Therefore, only trace amounts of nitric acid could have been in the filters, and no cellulose was present to form any nitrocellulose. It is estimated that no nitrocellulose is present in this waste stream.		
Organic acids (assumed to be ascorbic acid)	RFO-DOW-2H	See the evaluation of Versenes.	Clements (1982)	A best estimate is 7.1E+07 g
Organophosphates	RFO-DOW-15H	This stream reportedly contains trace quantities of organic laboratory waste such as organophosphates. Early plutonium recovery reportedly included a solvent extraction process using tributylphosphate. These organic compounds were probably disposed of in this stream. No data are available on quantities used at the RFP to make a reliable estimate. Assume that the organophosphates were usually used in a solvent extraction process and were combined with a kerosene or fuel oil compound such as dodecane. This combination would have been disposed of as part of the "other organic" constituents in this waste stream (57,493 gal buried). The "other organics" consist of 1,1,1-trichloroethane, trichloroethylene, tetrachloroethylene, and used oils. Organophosphates and kerosene were part of the "used oils." Assume that 10% of the volume of "other organics" (5,749 gal) contained organophosphates, and 25% of this volume (1,437 gal) were the organophosphates. Use a density of 1 g/mL. Thus, there would be 1,437 gal × 3,785 mL/gal × 1 g/mL = 5.4E+06 g organophosphates. Take all of this to be tributylphosphate.	Clements (1982), ChemRisk (1992b), and Kudera (1987)	A best estimate is 5.4E+06 g, assumed to be all tributylphosphate
PCBs	RFO-DOW-15H	Unknown volumes of oils containing PCBs were processed with other organic waste in this waste stream. The concentration of PCBs in the PCB oils processed may have exceeded 500 ppm in some cases. The PCB oils would have been part of the "other organic" constituents in this waste stream (57,493 gal). These "other organics" consist of 1,1,1-trichloroethane, trichloroethylene, tetrachloroethylene, and used oils. The PCB oils would have been part of the "used oils." Assume that 10% of the volume of "other organics" (5,749 gal) contained PCB oils and that 25% of this volume (1,437 gal) was actually PCB oils at a concentration of 500 ppm. Assume that the density of the PCBs is 0.9 g/mL. Thus, an estimate is 1,437 gal × 3,785 mL/gal × 0.9 g/mL × 5E-04 g PCB/g oil = 2.4E+03 g.	Clements (1982) and Kudera (1987)	A best estimate is 2.4E+03 g

Table D-1. (continued).

Contaminant	Streams where listed	Evaluation of possible upper-limit[a] quantity for each stream	Source(s) of information	Reasonable upper limit[a] on total unknown quantity over all streams shown
Sodium	D&D-IET-1H	Nearly all of the sodium was removed in a special processing operation. However, a few tens of grams of sodium are believed to have remained in the components that went to the SDA. It is assumed here that a maximum of 1E+02 g of sodium was disposed of in the SDA in this stream.	Detailed data form	An upper-limit estimate is 1E+02 g
	OFF-ATI-1H	It is believed that no bulk quantities of sodium were included in the shipments to the SDA. It is probable that small quantities of reacted or unreacted sodium were in the SDA waste. Aside from the statement that the quantities were likely small, there is no way to make an upper-limit estimate. The stream volume was large (1,390 m^3), but it included a large variety of waste.	Detailed data form; Clements (1980)	
Sodium nitrate	OFF-NMR-1H	The reference report indicates that the amount of sodium nitrate was small-to-trace quantities. The sodium nitrate resulted from neutralization of acidic radioactive waste solutions used in separation processes on laboratory samples. Most of the waste in the 3.96-m^3 stream is believed to be glassware, paper, soil, and cement. The sodium nitrate is estimated to be <5% of the stream total, i.e., <0.2 m^3, or <4.5E+05 g at a specific gravity of 2.26.	Detailed data form; Clements (1980)	An upper-limit estimate is 4.5E+05 g
Sodium-potassium	OFF-ATI-1H	It is believed that no bulk quantities of NaK were included in the shipments to the SDA. It is probable that small quantities of reacted or unreacted NaK were in the SDA waste. Aside from the statement that the quantities were likely small, there is no way to make an upper-limit estimate. The stream volume was large (1,390 m^3), but included a large variety of waste.	Detailed data form; Clements (1980)	There is no information to support an upper-limit estimate. The quantity is likely to be "small."
Terphenyl/diphenyl	CFA-690-1H	A note at the bottom of Part C of the data form states "P-terphenyl (Santo wax) with a CAS # of 92-94-4 was disposed of as a liquid with a quantity estimated of 90,754 gallons, ±10%." P-terphenyl (para terphenyl) is also called Santo Wax P. At a specific gravity of approximately 1.2, the quantity of contaminant would be 90,754 gal × 3,785 mL/gal × 1.2 g/mL = 4.1E+08 g.	Detailed data form	An upper-limit estimate is 5.9E+08 g of terphenyl and 1.8E+08 g of diphenyl.

Table D-1. (continued).

Contaminant	Streams where listed	Evaluation of possible upper-limit[a] quantity for each stream	Source(s) of information	Reasonable upper limit[a] on total unknown quantity over all streams shown
Terphenyl/diphenyl (continued)	PER-ORM-1H	The following information was obtained from a note at the bottom of Part C, as well as from Parts A and E of the data form: "Barrels disposed of were sometimes empty and sometimes full of Santo-R wax (especially 1963)." "Santo-Wax R consisted of terphenyl and diphenyl." "Many barrels of contaminated Santo-R wax disposed of at RWMC. Some were empty. Most were approximately 75% full." The total stream volume was 914.6 m^3. The stream was mostly scrap metals and combustibles. No information is available on the relative proportions of terphenyl and diphenyl in Santo-R Wax. It was assumed that one-third of the total stream volume was Santo-R wax, or 304.9 m^3. Santo-R wax was assumed to consist of equal portions of terphenyl and diphenyl. At a specific gravity of approximately 1.2, the quantity of terphenyl and diphenyl would be $1/2 \times 304.9\ m^3 \times 10^6\ mL/m^3 \times 1.2\ g/mL = 1.8E+08$ g each.	Detailed data form	
Toluene	OFF-WSU-1H	Most of the waste in the 2.15-m^3 stream is paper, glassware, animal carcasses, and aqueous solutions. The contaminant is believed to be <10% of the stream. Thus, an upper limit on the quantity of the contaminant would be 0.22 m^3, or 2.0E+05 g at a specific gravity of 0.9.	Detailed data form; Clements (1980)	An upper limit estimate is 2.0E+05 g
Versenes [assumed to be ethylenediaminetraacetic acid (EDTA)]	RFO-DOW-2H	Liquid waste was usually generated by the analytical laboratories and contained chemicals that could complex plutonium and keep it in solution during precipitation treatment. The complexing chemicals included alcohols, organic acids, and Versenes [trade name for a series of chelating agents based on ethylenediaminetetraacetic acid (EDTA)]. This liquid waste was processed separately with Portland cement to form a solid cement monolith. No quantities or specific chemical names of the complexing agents have been given; therefore, they are listed by only their generic name. Assume that 125 drums of this waste have been disposed of annually for 17 years (1954 through 1970). This is equal to 2,125 drums. It has been reported that 26.4 gal of liquids containing these chemicals was placed into each drum. No information is available on the concentration of these chemicals in the liquid. Assume that one-third of the volume (8.8 gal) is Versenes.	Clements (1982)	A best estimate is 7.1E+07 g

Table D-1. (continued).

Contaminant	Streams where listed	Evaluation of possible upper-limit[a] quantity for each stream	Source(s) of information	Reasonable upper limit[a] on total unknown quantity over all streams shown
Versenes [assumed to be ethylenediaminetraacetic acid (EDTA)](continued)	RFO-DOW-2H	Alcohols and organic acids are also assumed to be 8.8 gal each per drum. Assume that the density of the liquid is 1 g/mL. The amount of Versenes, alcohols, or organic acids in this stream is 8.8 gal/drum × 2,125 drums × 3,785 mL/gal × 1 g/mL = 7.1E+07 g each. Assumed specific compounds are, respectively, EDTA, ethyl alcohol, and ascorbic acid.		

a. As explained in the text, for waste from non-RFP generators, the estimates of the unknown quantities of contaminants are generally upper-limit estimates; for waste from the RFP, the estimates are generally best estimates. If the RFP was the dominant contributor of the unknown quantities of the contaminant, the estimate is called a best estimate. Otherwise, the estimate is generally called an upper-limit estimate.

Table D-2. Volumes and volume percents of each Rocky Flats Plant buried waste stream (based on 1971 through 1981 data).

Stream number	Stream name	Drums/year[a] (average)	Drum volume[a] (m^3/yr)	Boxes/year[b] (average)	Box volume[b] (m^3/yr)	Total volume (m^3/yr)	Volume percent of total
RFO-DOW-1H	Benelex, plexiglas	6.7	1.4	1.6	5.1	6.5	0.24
RFO-DOW-2H	Cemented sludges	123.7	25.8	—	—	25.8	0.94
RFO-DOW-3H	Uncemented sludges	1,543.9	321.4	—	—	321.4	11.72
RFO-DOW-4H	Combustibles	1,498.1	311.9	128.7	408.2	720.1	26.26
RFO-DOW-5H	Concrete, brick	166.2	34.6	19.5	61.9	96.4	3.52
RFO-DOW-6H	Filters	66.0	13.7	79.6	252.5	266.2	9.71
RFO-DOW-7H	Glass	267.1	55.6	0.1	0.3	55.9	2.04
RFO-DOW-8H	Glovebox gloves	70.9	14.8	—	—	14.8	0.54
RFO-DOW-9H	Metals	330.6	68.8	311.7	988.7	1,057.5	38.57
RFO-DOW-10H	Mixed waste	10.6	2.2	33.4	105.9	108.1	3.94
RFO-DOW-11H	Molds and crucibles	124.7	26.0	—	—	26.0	0.95
RFO-DOW-12H	Particulate	130.5	27.2	4.7	14.9	42.1	1.53
RFO-DOW-13H	Resins	2.9	0.6	—	—	0.6	0.02
RFO-DOW-14H	Salts	2.4	0.5	—	—	0.5	0.02
	Total	4,344.3	904.4	579.3	1,837.4	2,741.8	100.00

a. It is assumed that each drum is a 55-gal drum.

b. It is assumed that each box is 4 × 4 × 7 ft.

Table D-3. Total volume of Rocky Flats Plant buried waste streams RFO-DOW-1H through RFO-DOW-14H from 1954 through 1970.

Year	Volume from Lee (1971) (ft^3)	Volume of organic sludge (ft^3)	Volume of evaporator salt (ft^3)	Corrected volume (ft^3)	Corrected volume (m^3)
1954	23,992	—	—	23,992	679
1955	39,377	—	—	39,377	1,115
1956	41,814	—	—	41,814	1,184
1957	66,777	—	—	66,777	1,891
1958	58,240	—	—	58,240	1,649
1959	73,517	—	—	73,517	2,082
1960	68,683	—	—	68,683	1,945
1961	86,124	—	—	86,124	2,439
1962	97,281	—	—	97,281	2,755
1963	118,541	—	—	118,541	3,357
1964	132,936	—	—	132,936	3,765
1965	121,952	—	—	121,952	3,454
1966	171,555	1,963	—	169,592	4,803
1967	205,701	40,750	8,926	156,025	4,419
1968	345,765	17,580	20,601	307,584	8,711
1969	239,033	3,919	14,425	220,689	6,250
1970	347,765	7,124	20,719	319,922	9,060
Total	2,239,053	71,336	64,672	2,103,045	59,558

Table D-4. Estimated annual volumes (m^3) of Rocky Flats Plant waste streams RFO-DOW-1H through RFO-DOW-14H.

	Waste Stream														
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total
1954	1.63	6.38	79.58	178.31	23.90	65.93	13.85	3.67	261.89	26.75	6.45	10.39	0.14	0.14	**679**
1955	2.68	10.48	130.68	292.80	39.25	108.27	22.75	6.02	430.06	43.93	10.59	17.06	0.22	0.22	**1,115**
1956	2.84	11.13	138.76	310.92	41.68	114.97	24.15	6.39	456.67	46.65	11.25	18.12	0.24	0.24	**1,184**
1957	4.54	17.78	221.63	496.58	66.56	183.62	38.58	10.21	729.36	74.51	17.96	28.93	0.38	0.38	**1,891**
1958	3.96	15.50	193.26	433.03	58.04	160.12	33.64	8.90	636.02	64.97	15.67	25.23	0.33	0.33	**1,649**
1959	5.00	19.57	244.01	546.73	73.29	202.16	42.47	11.24	803.03	82.03	19.78	31.85	0.42	0.42	**2,082**
1960	4.67	18.28	227.95	510.76	68.46	188.86	39.68	10.50	750.19	76.63	18.48	29.76	0.39	0.39	**1,945**
1961	5.85	22.93	285.85	640.48	85.85	236.83	49.76	13.17	940.72	96.10	23.17	37.32	0.49	0.49	**2,439**
1962	6.61	25.90	322.89	723.46	96.98	267.51	56.20	14.88	1,062.60	108.55	26.17	42.15	0.55	0.55	**2,755**
1963	8.06	31.56	393.44	881.55	118.17	325.96	68.48	18.13	1,294.79	132.27	31.89	51.36	0.67	0.67	**3,357**
1964	9.04	35.39	441.26	988.69	132.53	365.58	76.81	20.33	1,452.16	148.34	35.77	57.60	0.75	0.75	**3,765**
1965	8.29	32.47	404.81	907.02	121.58	335.38	70.46	18.65	1,332.21	136.09	32.81	52.85	0.69	0.69	**3,454**
1966	11.53	45.15	562.91	1,261.27	169.07	466.37	97.98	25.94	1,852.52	189.24	45.63	73.49	0.96	0.96	**4,803**
1967	10.61	41.54	517.91	1,160.43	155.55	429.08	90.15	23.86	1,704.41	174.11	41.98	67.61	0.88	0.88	**4,419**
1968	20.91	81.88	1,020.93	2,287.51	306.63	845.84	177.70	47.04	3,359.83	343.21	82.75	133.28	1.74	1.74	**8,711**
1969	15.00	58.75	732.50	1,641.25	220.00	606.88	127.50	33.75	2,410.63	246.25	59.38	95.63	1.25	1.25	**6,250**
1970	21.74	85.16	1,061.83	2,379.16	318.91	879.73	184.82	48.92	3,494.44	356.96	86.07	138.62	1.81	1.81	**9,060**
Total	**142.94**	**559.85**	**6,980.20**	**15,639.93**	**2,096.44**	**5,783.08**	**1,214.98**	**321.61**	**22,971.52**	**2,346.59**	**565.80**	**911.24**	**11.91**	**11.91**	**59,558**
Vol %	0.24	0.94	11.72	26.26	3.52	9.71	2.04	0.54	38.57	3.94	0.95	1.53	0.02	0.02	**100%**

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Appendix E

Assumed Distributions of Generic Terms and Dual Entries for Radioactivity in the RWMIS Shipping Record Rollups for Use in the CIDRA Versus RWMIS Comparisons

Appendix E

Assumed Distributions of Generic Terms and Dual Entries for Radioactivity in the RWMIS Shipping Record Rollups, for Use in the CIDRA Versus RWMIS Comparisons

The Radioactive Waste Management Information System (RWMIS) shipping records contain generic entries [e.g., mixed activation products (MAP), mixed fission products (MFP)] for a substantial fraction of the radioactivity in the waste. Realistic comparisons of the activities of radionuclides in the Contaminant Inventory Database for Risk Assessment (CIDRA) database with those in RWMIS require that the generic entries first be replaced conceptually by radionuclide distributions. This appendix provides the distributions used for each major waste generator.

For the purpose *only* of the comparisons, the generic entries in RWMIS were replaced conceptually using the simplified method described below. *The conceptual replacement of the generic entries does not replace or affect the detailed distributions used in CIDRA in any way, nor were the generic entries in RWMIS actually replaced.*

The method used to conceptually replace the generic entries in RWMIS was based on a simplified application of the radionuclide distributions in CIDRA. For several major waste generators [Test Area North (TAN), Test Reactor Area (TRA), and Naval Reactors Facility (NRF)], the distributions in CIDRA generally differ from one waste stream to another because nuclear physics calculations were used to develop the distributions. For these generators, simplified (approximate average) distributions were developed and used in these comparisons to replace the RWMIS generic entries for the generator.

For other major waste generators [Idaho Chemical Processing Plant (ICPP) and Argonne National Laboratory-West (ANL-W)], fixed distributions generally had been used by the data gatherers each time a generic entry was identified in the records for a generator (see Sections 2.4.3 and 2.4.5, respectively). For these generators, the same radionuclide distributions were used for the comparisons as were used when the information was entered into CIDRA. Generic entries for waste from the other category of generators were handled similarly in the comparisons.

RWMIS contains no generic entries for Rocky Flats Plant (RFP) waste.

RWMIS also contains many dual-radionuclide entries (e.g., Zr-Nb-95). The assumptions made for these entries in the comparisons are also listed in this appendix.

A. ASSUMED DISTRIBUTIONS OF DUAL-RADIONUCLIDE ENTRIES IN RWMIS

RWMIS entry	Assumed distribution	Remarks
Zr-Nb-95	0.5 Zr-95, 0.5 Nb-95	Assumed to be in equilibrium
Sr-Y-90	0.5 Sr-90, 0.5 Y-90	Assumed to be in equilibrium
Ce-Pr-144	0.5 Ce-144, 0.5 Pr-144	Assumed to be in equilibrium
Ru-Rh-106	0.5 Ru-106, 0.5 Rh-106	Assumed to be in equilibrium
Ba-La-140	0.5 Ba-140, 0.5 La-140	Assumed to be in equilibrium
Sr-89-90	All Sr-90	Conservative assumption[a]
Ce-141-144	All Ce-144	Conservative assumption[a]

B. MISCELLANEOUS ASSUMPTIONS CONCERNING RADIONUCLIDE ENTRIES IN RWMIS

Sn-119	Convert to Sn-119m	Sn-119 is not radioactive

C. ASSUMED DISTRIBUTIONS OF GENERIC RADIONUCLIDE TERMS IN RWMIS

(Totals may not always add to exact unity because of round-off.)

1. Test Area North

Term	RWMIS activity (Ci)	Assumed distribution: Nuclide	Assumed distribution: Fraction
MAP	2.4E+04	Fe-55	0.349
		Co-60	0.334
		Ni-59	0.115
		Mn-54	0.059
		Fe-59	0.048
		Cr-51	0.041
		Co-58	0.033
		Nb-95	0.012
		Ni-63	0.009
		Total	1.000
MFP	2.0E+04	Cs-137	0.246
		Sr-90	0.117
		La-140	0.095
		Ce-141	0.087
		Ba-140	0.081
		Pr-143	0.076

a. Conservative in terms of half-life and radiotoxicity.

Term	RWMIS activity (Ci)	Assumed distribution	
		Nuclide	Fraction
MFP (continued)		Zr-95	0.069
		Y-91	0.065
		Sr-89	0.058
		Ru-103	0.044
		Rh-103m	0.033
		Ce-144	0.025
		H-3	0.004
		Total	1.000
Unidentified beta-gamma	1.5E+02	Cs-137	0.503
		Sr-90	0.497
		Total	1.000
Unidentified alpha	1.0E-01	Same as for TRA	

2. Test Reactor Area

Term	RWMIS activity (Ci)	Assumed distribution	
		Nuclide	Fraction
MAP	7.4E+05	Co-60	0.53
		Ni-63	0.40
		H-3	0.06
		C-14	0.01
		Total	1.00
MFP	9.5E+05	Cs-137	0.69
		Ce-144	0.22
		Sb-125	0.04
		Eu-155	0.032
		Sr-90	0.012
		Tc-99	0.0009
		I-129	5×10^{-8}
		Total	1.00
Unidentified beta-gamma	1.2E+05	Co-60	0.41
		Ni-63	0.31
		Cs-137	0.15
		H-3	0.05
		Ce-144	0.05
		C-14	0.009
		Sb-125	0.008

Term	RWMIS activity (Ci)	Assumed distribution	
		Nuclide	Fraction
Unidentified beta-gamma (continued)		Eu-155	0.007
		Sr-90	0.003
		Ni-59	0.0004
		Tc-99	0.0002
		I-129	2×10^{-8}
		Total	1.00
Unidentified alpha	2.0E+00	Cm-242	0.26
		Pu-239	0.24
		Pu-238	0.22
		Am-241	0.12
		Cm-244	0.12
		Pu-240	0.04
		Total	1.00

3. Idaho Chemical Processing Plant

Term	RWMIS activity (Ci)	Assumed distribution	
		Nuclide	Fraction
MAP	2.3E+04	Co-58	0.500
		Mn-54	0.500
		Total	1.000
MFP	1.0E+05	Ce-144	0.197
		Pr-144	0.197
		Cs-137	0.100
		Sr-90	0.100
		Y-90	0.100
		Ru-106	0.100
		Rh-106	0.100
		Sb-125	0.044
		Zr-95	0.031
		Nb-95	0.031
		Total	1.000
Unidentified beta-gamma	1.2E+03	Ce-144	0.197
		Pr-144	0.197
		Cs-137	0.100
		Sr-90	0.100
		Y-90	0.100
		Ru-106	0.100

Term	RWMIS activity (Ci)	Assumed distribution: Nuclide	Fraction
Unidentified beta-gamma (continued)		Rh-106	0.100
		Sb-125	0.044
		Zr-95	0.031
		Nb-95	0.031
		Total	1.000
Unidentified alpha	None		

4. Naval Reactors Facility

Term	RWMIS activity (Ci)	Assumed distribution: Nuclide	Fraction
MAP	2.9E+04	Co-60	0.50
		Fe-55	0.40
		Ni-63	0.10
		Total	1.00
MFP	5.4E+05	Sr-90	0.50
		Cs-137	0.50
		Total	1.00
Unidentified beta-gamma	3.9E+05	Co-60	0.50
		Fe-55	0.40
		Ni-63	0.10
		Total	1.00
Unidentified alpha	3.9E-03	Same as for TRA	

5. Argonne National Laboratory-West

Term	RWMIS activity (Ci)	Assumed distribution: Nuclide	Fraction
MAP	1.8E+03	Co-60	0.55
		Cr-51	0.20
		Mn-54	0.15
		Co-58	0.10
		Total	1.00

Term	RWMIS activity (Ci)	Assumed distribution	
		Nuclide	Fraction
MFP	3.4E+04	Sr-90	0.50
		Cs-137	0.30
		Ce-144	0.20
		Total	1.00
Unidentified beta-gamma	8.0E+03	Sr-90	0.50
		Cs-137	0.30
		Ce-144	0.20
		Total	1.00
Unidentified alpha	6.4E-01	Same as for TRA	

6. Rocky Flats Plant

No generic entries

7. Other

Term	RWMIS activity (Ci)	Assumed distribution	
		Nuclide	Fraction
MAP	8.8E+02	Co-60	0.75
		Fe-59	0.25
		Total	1.00
MFP	3.3E+04	Cs-137	0.50
		Sr-90	0.50
		Total	1.00
Unidentified beta-gamma	3.0E+03	Co-60	0.375
		Cs-137	0.25
		Sr-90	0.25
		Fe-59	0.125
		Total	1.000
Unidentified alpha	1.3E-02	Same as for TRA	

Appendix F

Summary of Results of Environmental Monitoring at the Subsurface Disposal Area

Appendix F

Summary of Results of Environmental Monitoring at the Subsurface Disposal Area

This appendix provides summary tables of environmental monitoring results at the Subsurface Disposal Area (SDA). These summary tables provide a broad indication of what contaminants have been detected in the monitoring for comparison with the data compiled in Contaminant Inventory Database for Risk Assessment (CIDRA) database. Separate tables are given for radiological and nonradiological contaminants. Within each table, separate entries are also provided for the results of routine monitoring and special studies because the statistical criteria often varied in the studies.

The radiological contaminants, which are presented in Table F-1, include those most frequently detected in Radioactive Waste Management Complex (RWMC) environmental samples and others included in routine screening tests. Monitoring data included in this review span 18 years (1976 through 1993); however, only years for which detectable levels were reported appear in Table F-1.

Because Table F-1 is a high-level rollup table for comparison only, the minimum and maximum reported values of concentration were compiled for each medium by combining the results from all of the sampling methods. If only one sample was evaluated, only the single result is listed in the table. Air contaminant concentrations include data from both high- and low-volume air samplers. Soil concentrations include both surface and near-surface values. Concentrations in subsurface sediments (deeper than near-surface) are reported separately. Contaminant concentrations in samples from all monitoring wells were combined to report a range of concentrations. No distinction between sampling locations within the SDA, monitoring instrumentation, sampling locations, or number of positive samples was considered in this rollup table. Only a gross range in concentration values is presented.

The environmental medium terms (e.g., groundwater, subsurface water, and perched water) used in the routine monitoring and special studies reports to describe the subsurface have not always been defined clearly or used consistently. Because the purpose here is to indicate which contaminants have been detected, not the environmental media in which they were detected, no attempt is made to define what is meant by the various terms. The contaminant concentrations are presented with their associated environmental medium term used in the cited report.

Below-measurable concentrations are denoted as below detection limit (BDL). Detection limits for major radiological contaminants monitored at the SDA are included in the annual monitoring reports. Significant concentration results generally reflect a 95% confidence level, and the uncertainty for analytical results is $\pm 2\ \sigma$ for radionuclides. Data reported for biotic vegetation and air sampling are provided by analyses conducted by the Radiological and Environmental Sciences Laboratory (RESL).

Table F-2 summarizes results of routine monitoring and special studies for nonradiological contaminants. Monitoring for nonradiological contaminants is smaller in scope than monitoring for radiological contaminants. Organic compounds and metals have been monitored regularly at the SDA since 1987. Special studies were conducted in the years listed in Table F-2. Maximum and minimum contaminant concentrations are presented for each medium sampled.

Generally, data reported for nonradiological contaminants reflect an uncertainty of $\pm 1\ \sigma$. Below-measurable levels are indicated as practical quantitation level (PQL). PQL values for nonradiological contaminants measured in the SDA are given in the annual monitoring reports.

The detection of contaminants in environmental media at the RWMC does not always imply that the contaminants came from the inventoried SDA waste. Contaminants detected in environmental samples collected at the RWMC could have also resulted from (a) emissions from other Idaho National Engineering Laboratory (INEL) facilities, (b) atmospheric fallout from weapons testing, (c) natural occurrence, (d) cross-contamination or erroneous laboratory analysis, or (e) waste located in other parts of the RWMC. Eliminating the other potential sources of contamination requires rigorous design and execution of the sampling and analysis and careful interpretation of the results. Such evaluations are beyond the scope of these simplified comparisons.

The special studies cited in this appendix, RESL data, and subsurface water sampling and analysis by the U.S. Geological Survey (USGS) are believed to be of acceptable reliability for use in the comparisons. However, in spite of rigorous monitoring activities, contaminants in aquifer samples collected by the USGS at the RWMC could have been the result of waterborne effluents upgradient from other INEL facilities. A case-by-case analysis is required to postulate the source of each detected contaminant.

The data from INEL contractor routine monitoring at the RWMC before approximately 1983 are considered to be of lower reliability. Quality assurance of the monitoring activities was minimal. In many cases, no control samples were collected or the control samples were from inappropriate locations. In 1983, detailed reviews of the objectives, procedures, and data were completed for the INEL contractor monitoring activities at the RWMC, which led to major improvements in sampling design, laboratory analysis, data evaluation, and quality assurance. The monitoring activity reviews continue to be held regularly. For the INEL contractor routine monitoring, only contaminant concentrations in air, subsurface and surface water, and subsurface and surface soil data obtained in 1984 or later are considered sufficiently reliable for these comparisons. For the present comparisons, the biotic data from all years are considered reliable.

The summary environmental monitoring data are not compared here against background concentrations of the contaminants. Some of the listed detections may represent concentrations of contaminants at background levels.

Table F-1. Summary of results from routine monitoring and special studies for radiological contaminants.

Contaminant	Environmental medium	Years in which contaminant was sampled for and detected[a]	Concentration range
Ac-228	Aquifer	(EMU) 1979	(2.2±1.7)E-07 μCi/mL
Ag-110m	Air	(EMU) 1980	(0.26±0.10 to 0.39±0.12)E-13 μCi/mL
	Surface water	(EMU) 1977	6.0E-10 μCi/mL
	Soil	(EMU) 1979-1980	BDL to (1.12±0.32)E-07 μCi/g
Am-241	Aquifer	(EMU) 1976, 1981, 1982, 1984, (SS) 1987	(1.5±0.6)E-11 to (2.0±1.0)E-10 μCi/mL BDL to (5.3±1.3)E-10 μCi/mL
	Perched water	(SS) 1976–1977	BDL
	Surface water	(EMU) 1977, 1983-1985, 1990, 1991, 1992, 1993 (SS) 1984	(1.2±0.2)E-10 to 2.5E-08 μCi/mL (88.6±7.2)E-08 μCi/mL
	Surficial sediment	(SS) 1989	(13±2 to 154,000±3,000)E-15 Ci/g
	Subsurface sediment	(SS) 1975–1977, 1985–1988, 1989	BDL to (1.55±0.4)E-03 μCi/g
	Soil	(EMU) 1977-1981, 1984, 1986, 1988, 1991, 1992 (SS) 1986, 1989, 1992	BDL to (981.0±82.0)E-07 μCi/g (8.0±2.0)E-9 to (1.54±0.03)E-04 μCi/g
	Biota—vegetation	(EMU) 1984, 1986, 1987, 1990, 1991, 1992, 1993	BDL to (3.9±0.6)E-08 μCi/g
	Biotic—soil	(EMU) 1984-1986, 1990	4.0E-08 to (32.0±3.0)E-06 μCi/g
	Biotic—tissue	(EMU) 1987, 1989	BDL to (4.7±0.3)E-07 μCi/g
	Air	(EMU) 1978-1981, 1984–1993	(1.6±0.4)E-17 to 9.8E-14 μCi/mL
Ba-140	Air	(EMU) 1980	(5.0±2.0 to 8.0±4.0)E-15 μCi/mL
Ce-141	Aquifer	(EMU) 1983	(0.180±0.075)E-06 μCi/mL
	Perched water	(SS) 1976–1977	BDL
	Surface water	(EMU) 1977, 1981	5.6E-08 to (3.08±2.56)E-09 μCi/mL
	Soil	(EMU) 1979–1981	(0.65±0.27 to 4.81±1.94)E-07 μCi/g
	Air	(EMU) 1978-1981, 1983–1984	(0.49±0.2)E-15 to 7.90E-14 μCi/mL

Table F-1. (continued).

Contaminant	Environmental medium	Years in which contaminant was sampled for and detected[a]	Concentration range
Ce-144	Perched water	(SS) 1976–1977	BDL
	Subsurface sediment	(SS) 1975–1978	BDL to (3.92±0.57)E-07 μCi/g
	Surface water	(EMU) 1976–1979	(35.4±7.4)E-09 to 1.3E-06 μCi/mL
	Soil	(EMU) 1978–1981	(1.16±0.47 to 117.0±36.0)E-07 μCi/g
	Air	(EMU) 1978–1981, 1983–1984	(0.7±0.4)E-15 to 3.93E-12 μCi/mL
Co-58	Soil	(EMU) 1978–1981	(0.41±0.4 to 1.40±0.45)E-07 μCi/g
	Air	(EMU) 1978–1981, 1983, 1985	(0.67±0.15)E-15 to 1.04E-13 μCi/mL
Co-60	Aquifer	(EMU) 1980 (SS) 1987	(0.11±0.10)E-07 μCi/mL BDL
	Perched water	(SS) 1976–1977	BDL
	Subsurface sediment	(SS) 1976–1988, 1989	BDL to 2.8E-04 pCi/g
	Surface water	(EMU) 1977	1.80E-09 μCi/mL
	Surficial sediment	(SS) 1989	(24±8 to 360±17)E-15 Ci/g
	Soil	(EMU) 1977–1981 (SS) 1978, 1986	(1.25±0.61 to 266.0±8.0)E-07 μCi/g BDL to (9.23±0.31)E-07 μCi/g
	Biota—vegetation	(EMU) 1983	(0.7±0.2 to 1.0±0.3)E-06 μCi/g
	Biotic—soil	(EMU) 1984	(0.77±0.14)E-06 μCi/g
	Biotic—tissue	(EMU) 1987, 1991, 1992	(1.84±0.18 pCi/g to 6.7±0.7)E-07 μCi/g
	Air	(EMU) 1978–1981, 1983, 1986	(0.89±0.32)E-15 to 1.75E-12 μCi/mL
Cr-51	Surface water	(EMU) 1977	5.30E-09 μCi/mL
	Soil	(EMU) 1978–1981	(4.63±2.76 to 19.3±5.9)E-07 μCi/g
	Air	(EMU) 1978–1981, 1983	(4.94)E-15 to 1.80E-12 μCi/mL

Table F-1. (continued).

Contaminant	Environmental medium	Years in which contaminant was sampled for and detected[a]	Concentration range
Cs-134	Surface water	(EMU) 1977, 1979, 1981	(0.89±0.69 to 8.6±1.04)E-09 μCi/mL
	Soil	(EMU) 1978-1981	(0.68±0.33 to 16.1±0.57)E-07 μCi/g
	Biota—vegetation	(EMU) 1987	(1.07±0.14 to 1.5±0.2)E-07 μCi/g
	Air	(EMU) 1978-1981, 1985	(1.11±0.46)E-15 to 1.03E-13 μCi/mL
Cs-137	Aquifer	(EMU) 1976-1977, 1980, 1986 (SS) 1987	(1.6±0.7)E-08 to (0.09±0.03)E-06 μCi/mL BDL
	Perched water	(SS) 1976-1977	BDL
	Subsurface sediment	(SS) 1975-1988, 1989	BDL to (1,090±30)E-05 μCi/g
	Surface water	(EMU) 1976-1977, 1979-1981, 1983-1986, 1988, 1990, 1993	(1.4±0.4)E-09 to (202.4±0.36)E-08 μCi/mL
	Surficial sediment	(SS) 1989	(27±8 to 1,800±70)E-15 Ci/g
	Soil	(EMU) 1977-1981, 1984, 1988, 1992 (SS) 1978, 1989	(1.13±0.43)E-07 to (40±2.0)E-06 μCi/g (1.8±7.0)E-08 to (153±0.05)E-06 μCi/g
	Biota—vegetation	(EMU) 1983-1984, 1987	(0.69±0.19)E-07 to (2.8±0.2)E-04 μCi/g
	Biotic—soil	(EMU) 1984, 1986, 1990	(8.0E-08 to 0.94±0.24)E-06 μCi/g
	Biotic—tissue	(EMU) 1987, 1991, 1992	(4.1±0.8)E-07 to (7.32±0.23)E-06 μCi/g
	Air	(EMU) 1978-1981, 1984-1985, 1987, 1991	(0.5±0.2)E-15 to (9.08±0.47)E-13 μCi/mL
Eu-152	Surface water	(EMU) 1976, 1978-1979	0.78E-09 to (1.8±0.4)E-08 μCi/mL
	Soil	(EMU) 1978-1981 (SS) 1978	(1.56±1.55)E-07 to 1.06E-06 μCi/g BDL to (2.06±0.36)E-07 μCi/g
	Air	(EMU) 1978-1981	(9.25±2.39)E-15 to (9.57±1.37)E-13 μCi/mL
	Biotic—tissue	(EMU) 1987	(14.3±1.8 to 52.4±1.8)E-07 μCi/g

Table F-1. (continued).

Contaminant	Environmental medium	Years in which contaminant was sampled for and detected[a]	Concentration range
Eu-154	Subsurface sediment	(SS) 1985	(29±9)E-09 µCi/g
	Surface water	(EMU) 1976, 1979	(8.6±1.76)E-09 to (1.7±0.3)E-08 µCi/mL
	Surficial sediment	(SS) 1989	29±9E-15 Ci/g
	Soil	(EMU) 1979–1981 (SS) 1978, 1989	(1.82±0.64 to 3.20±1.21)E-07 µCi/g BDL to (2.74±0.28)E-07 µCi/g
	Biotic—tissue	(EMU) 1987	(7.4±1.3 to 39±3)E-07 µCi/g
	Air	(EMU) 1978–1981	(3.10±1.50)E-15 to (2.09±0.82)E-13 µCi/mL
Eu-155	Air	(EMU) 1981	(5.31±2.1)E-15 to (1.13±0.36)E-13 µCi/mL
	Soil	(EMU) 1981	(3.23±1.46)E-07 µCi/g
Fe-59	Aquifer	(EMU) 1976	(2.1±0.7)E-08 µCi/mL
	Soil	(EMU) 1979–1981	BDL to (2.47±0.71)E-07 µCi/g
	Air	(EMU) 1978–1981	BDL to 4.29E-13 µCi/mL
H-3	Aquifer	(EMU) 1977–1993 (SS) 1984–1986, 1987	(6.0±4.0)E-07 to (2.7±0.4)E-06 µCi/mL <BDL to (1.9±0.4)E-06 µCi/mL
	Perched water	(SS) 1976–1977 (EMU) 1992, 1993	(5.4±0.1 to 18.0±1.0)E-06 µCi/mL BDL to (0.4±0.2)E-06 µCi/mL
Hf-181	Soil	(EMU) 1978–1981	(0.30±0.27 to 4.40)E-07 µCi/g
	Air	(EMU) 1978–1981	1.21E-15 to (1.58±0.77)E-13 µCi/mL
Hg-203	Soil	(EMU) 1980–1981	(0.90±0.39 to 2.14±0.63)E-07 µCi/g
	Air	(EMU) 1978–1981	(0.54±0.43)E-15 to (0.65±0.42)E-13 µCi/mL

Table F-1. (continued).

Contaminant	Environmental medium	Years in which contaminant was sampled for and detected[a]	Concentration range
I-131	Air	(EMU) 1980	BDL to (0.9±0.6)E-15 μCi/mL
Mn-54	Aquifer	(EMU) 1977	(1.8±0.7 to 1.9±0.7)E-08 μCi/mL
	Soil	(EMU) 1979–1981	(0.60±0.44 to 1.74±0.59)E-07 μCi/g
	Air	(EMU) 1978–1981, 1983	BDL to (1.19±1.03)E-13 μCi/mL
Nb-95	Surface water	(EMU) 1977	5.70E-07 μCi/mL
	Soil	(EMU) 1978–1981	(0.82±0.27 to 4.0)E-07 μCi/g
	Air	(EMU) 1978–1981	(1.22±0.18 to 3.48±1.5)E-13 μCi/mL
Pb-212	Aquifer	(EMU) 1978	(5.3±2.6)E-08 μCi/mL
Pu-238	Aquifer	(EMU) 1981, 1983 (SS) 1987	(1.0±0.8 to 8.1±0.8)E-10 μCi/mL Not detected
	Perched water	(SS) 1976–1977, 1989	BDL to (3.22±0.17)E-08 μCi/mL
	Surface water	(EMU) 1983	(0.015±0.004)E-08 μCi/mL
	Surficial sediment	(SS) 1989	(5.2±1.7 to 6,400±200)E-15 Ci/g
	Subsurface sediment	(SS) 1975–1988, 1989	BDL to (3.8±0.4)E-07 μCi/g
	Soil	(EMU) 1979–1981, 1988, 1991 (SS) 1989 (SS) 1992	(0.009±0.008 to 0.72±5.0)E-06 μCi/g (3.8±0.4)E-07 μCi/g (7.2±1.5)E-08 to (4.0±0.3)E-06 μCi/g
	Soil water	(SS) 1989	(5.3±1.3)E-10 μCi/mL
	Biota—vegetation	(EMU) 1984, 1986–1987, 1990	BDL to (0.08±0.01)E-06 μCi/g
	Biotic—tissue	(EMU) 1987, 1989	BDL to (2.2±0.2)E-07 μCi/g
	Air	(EMU) 1980, 1986–1988	(4±1)E-18 to (5.0±0.08)E-15 μCi/mL

Table F-1. (continued).

Contaminant	Environmental medium	Years in which contaminant was sampled for and detected[a]	Concentration range
Pu-239/240	Aquifer	(SS) 1985–1986, 1987	BDL
	Perched water	(EMU) 1976 (SS) 1989	(0.25±0.09)E-10 μCi/mL (5.8±0.2)E-08 μCi/mL
	Subsurface sediment	(SS) 1975–1978, 1985–1988, 1989	BDL to (11±0.5)E-03 μCi/g
	Surface water	(EMU) 1983–1985	(0.016±0.006 to 0.15±0.06)E-08 μCi/mL
	Surficial sediment	(SS) 1989	(5.5±1.6 to 33,400±600)E-15 Ci/g
	Soil	(EMU) 1976–1977, 1979–1981, 1986, 1988, 1991, 1992, 1993 (SS) 1989 (SS) 1992	BDL to (0.23±0.05)E-07 μCi/g (3.34±0.06)E-05 μCi/g (6.0±1.5)E-08 to (1.16±0.07)E-05 μCi/g
	Soil water	(SS) 1989	(8±7)E-11 μCi/g
	Biota—vegetation	(EMU) 1986, 1987, 1990	(1.0±0.2)E-08 to (1.05±0.08)E-06 μCi/g
	Biotic—soil	(EMU) 1984, 1986-1990	(4.0E-08 to 16.5±0.8)E-06 μCi/g
	Biotic—tissue	(EMU) 1987, 1989	(2.7±0.8 to 30±2)E-08 μCi/g
	Air	(EMU) 1980, 1984-1988, 1990-1993	(2.0±0.6)E-18 to (1.8±0.1)E-15 μCi/mL
Ru-103	Surface water	(EMU) 1977, 1981	(2.78±0.79)E-09 to 1.40E-07 μCi/mL
	Soil	(EMU) 1978–1981	(0.70±0.38 to 3.50)E-07 μCi/g
	Air	(EMU) 1978–1980, 1983	(1.07±0.93)E-15 to 1.12E-13 μCi/mL
Ru-106	Surface water	(EMU) 1976–1977, 1979	(30±11 to 32.2±6.2)E-09 μCi/g/mL
	Soil	(EMU) 1979–1981	(4.18±2.40)E-07 to 2.26E-06 μCi/g
	Biota—vegetation	(EMU) 1978	2.44E-06 μCi/g
	Air	(EMU) 1978–1981	(14.0±3.4)E-15 to (5.88±1.83)E-13 μCi/mL
Sb-124	Soil	(EMU) 1979–1981	(0.53±0.24 to 1.13±0.43)E-07 μCi/g
	Air	(EMU) 1979–1981	(1.02±0.27)E-15 to (0.58±0.15)E-13 μCi/mL

Table F-1. (continued).

Contaminant	Environmental medium	Years in which contaminant was sampled for and detected[a]	Concentration range
Sb-125	Surface water	(EMU) 1978-1981	(1.40±0.67 to 7.35±1.31)E-07 μCi/mL
	Soil	(EMU) 1978-1981	(1.40±0.67 to 7.35±1.31)E-07 μCi/g
	Biotic—tissue	(EMU) 1987	BDL to 7.8±1.2E-07 μCi/g
	Biota—vegetation	(EMU) 1987	(1.6±0.3 to 1.8±0.4)E-07 μCi/g
	Air	(EMU) 1978-1981, 1984	BDL to (310±100)E-15 μCi/mL
Sc-46	Soil	(EMU) 1979-1981	(0.84±0.61 to 1.78±0.65)E-07 μCi/g
	Air	(EMU) 1978-1981	(0.59±0.42)E-15 to (0.52±0.20)E-13 μCi/mL
Sr-90	Aquifer	(EMU) 1978-1979, 1985-1987 (SS) 1987	(5.0±4.0)E-09 to (2.3±0.3)E-08 μCi/mL BDL to (0.7±0.14)E-08 μCi/mL
	Perched water	(EMU) 1976, 1980, 1988	BDL to (0.09±0.04)E-07 μCi/mL
	Subsurface sediment	(SS) 1975-1988, 1989	BDL to (1.28±0.04)E-06 μCi/g
	Surface water	(EMU) 1987	(<1.6±0.3)E-09 to (1.70±0.10)E-06 μCi/mL
	Surficial sediment	(SS) 1989	(58±19 to 1,280±40)E-15 Ci/g
	Soil	(EMU) 1988, 1991, 1992 (SS) 1989	(0.22±0.7 to 2.2±0.2)E-06 μCi/g (1.28±0.04)E-06 μCi/g
	Biotic—soil	(EMU) 1984	(0.11±0.01 to 0.6±01)E-06 μCi/g
	Biota—vegetation	(EMU) 1983-1984, 1986-1987, 1990, 1992, 1993	(9±2)E-08 to 8.7E-02 μCi/g
	Biotic—tissue	(EMU) 1987, 1989	(2.5±0.3 to 6.5±0.5)E-07 μCi/g
	Air	(EMU) 1986, 1987, 1988, 1993	(8±2)E-17 to (5.5±0.9)E-16 μCi/mL
Ta-182	Soil	(EMU) 1979-1981	(2.23±1.14 to 3.84±1.46)E-07 μCi/g
	Air	(EMU) 1979-1981	(4.30±1.78)E-15 to (3.50±1.00)E-13 μCi/mL

Table F-1. (continued).

Contaminant	Environmental medium	Years in which contaminant was sampled for and detected[a]	Concentration range
U-234	Soil	(EMU) 1986 (SS) 1992	4.0±1.0E-07 μCi/g (7.9±1.0)E-7 to (1.39±0.11)E-06 μCi/g
	Biota—vegetation	(EMU) 1985, 1987	(2.3±0.3 to 3.9±0.5)E-08 μCi/g
	Biotic—tissue	(EMU) 1987	(2.8±0.4)E-08 to (3.6±0.4)E-07 μCi/g
U-235	Soil	(SS) 1983	(0.34±0.003 to 0.06±0.01)E-06 μCi/g
	Biota—vegetation	(EMU) 1987	(1.6±0.5 to 2.3±0.6)E-09 μCi/g
	Biotic—tissue	(EMU) 1987, 1989	BDL to 1.4±0.2E-08 μCi/g
U-237	Air	(EMU) 1980	(1.6±1.0 to 8.0±2.0)E-15 μCi/mL
U-238	Soil	(SS) 1983-1984, 1992	(8.0±1.0)E-07 to (1.43±0.1)E-06 μCi/g
	Biota—vegetation	(EMU) 1987	(2.9±0.4 to 4.0±0.6)E-08 μCi/g
	Biotic—tissue	(EMU) 1987, 1989	(2.5±0.4)E-08 to (1.2±0.2)E-07 μCi/g
Y-91	Soil	(EMU) 1979-1980	BDL to (934±538.0)E-07 μCi/g
	Air	(EMU) 1979-1980	(1.46±1.14)E-15 to (322±84.0)E-13 μCi/mL
Zn-65	Soil	(EMU) 1979-1981	BDL to (1.93±0.83)E-07 μCi/g
	Air	(EMU) 1978-1981	BDL to (1.11±0.90)E-13 μCi/mL
Zr-95	Surface water	(EMU) 1977	3.4E-07 μCi/mL
	Soil	(EMU) 1979-1981	(1.55±0.93 to 5.00)E-07 μCi/g
	Air	(EMU) 1978-1981	(1.54±0.66 to 168.0±8.0)E-15 μCi/mL

a. Years spanned by environmental monitoring results (EMU) presented here are 1976 through 1993. Results from special studies (SS) span years as shown.

BDL — Below detection limit.
EMU — Data compiled from routine monitoring results published by the Environmental Monitoring Unit.
SS — Special studies. Data compiled from studies other than those that are part of the routine monitoring program.

Table F-2. Summary of results from routine monitoring and special studies for nonradiological contaminants.

Contaminant	Medium	Years in which contaminant was detected[a]	Concentration
ORGANICS			
1,1,1-trichloroethane	Aquifer, perched	(EMU) 1987–1993 (SS) 1987–1988, 1993	<0.2 to 0.9 μg/L <0.2 to 15.0 μg/L
	Soil/soil gas	(SS) 1987	<0.01 μg/L
	Borehole vapor	(SS) 1987, 1988	BDL to 120 mg/m^3
	Air	(SS) 1991, 1994	1.4 $\mu g/m^3$
1,1,2-trichlorotrifluoroethane	Perched water	(EMU) 1987–1990 (SS) 1987–1988	37 to 250 μg/L <0.2 to 250 μg/L
	Air	(SS) 1989	24 to 120 mg/m^3
	Soil borehole vapor	(SS) 1987	PQL to 120 μg/L
	Soil/soil gas	(SS) 1987	NR to 310 μg/L
1,1-dichloroethane	Aquifer	(EMU) 1987–1993 (SS) 1987–1988, 1990–1991	<0.2 to 5.6 μg/L <0.2 to 13 μg/L 5.6 to 22 μg/L
	Perched water	(EMU) 1987–1990 (SS) 1987, 1993	5.6 to 22 μg/L 0.3 to 13 μg/L
1,1-dichloroethylene	Aquifer	(EMU) 1987–1993 (SS) 1987–1988, 1990–1991	<0.2 to 1.0 μg/L <0.2 to 3.0 μg/L
	Perched water	(EMU) 1987–1990 (SS) 1987	0.8 to 2.6 μg/L <0.8 μg/L
2-butanone	Air	(SS) 1994	0.4 $\mu g/m^3$
Acetone	Sedimentary interbed	(SS) 1987	11 μg/kg
	Air	(SS) 1994	3.0 $\mu g/m^3$
Carbon tetrachloride	Aquifer	(EMU) 1987–1993 (SS) 1987–1991	<0.2 to 2.8 μg/L <0.2 to 6.6 μg/L
	Perched water	(EMU) 1987–1990 (SS) 1987, 1988, 1993	230 to 1,400 μg/L <0.2 to 2,100 μg/L
	Air	(SS) 1987, 1989	17 to 5,800 mg/m^3
	Borehole vapor	(EMU) 1987 (SS) 1987–1988	0.1 to 36 mg/m^3 BDL to 5,800 μg/L
	Soil/soil gas	(SS) 1987, 1992	0.22 to 1,400 ppb

Table F-2. (continued).

Contaminant	Medium	Years in which contaminant was detected[a]	Concentration
Chloroform	Aquifer	(EMU) 1987–1993 (SS) 1987–1991	<0.2 to 1.0 μg/L <0.2 to 3 μg/L
	Perched water	(EMU) 1987–1990 (SS) 1987–1988, 1990–1991, 1993	300 to 940 μg/L <0.2 to 1,500 μg/L
	Air	(SS) 1989, 1994	1.7 to 320,000 μg/m³
	Soil/borehole vapor	(SS) 1987, 1988, 1992	BDL to 330 μg/L
	Sedimentary interbed	(SS) 1987	120 μg/kg
Dichlorodifluoromethane	Aquifer	(EMU) 1987–1993 (SS) 1987–1991	<0.2 to <2.6 μg/L <0.2 to 3.0 μg/L
	Air	(SS) 1994	0.3 μg/m³
	Perched water	(EMU) 1987–1990 (SS) 1987–1988, 1990–1991	BDL to 0.3 μg/L <0.2 to 3 μg/L
Methylene chloride	Sedimentary interbed	(SS) 1987	42 μg/kg
	Perched water	(SS) 1993	BDL to <100 μg/L
	Air	(SS) 1991, 1994	0.05 μg/m³
Phenol	Aquifer	(SS) 1991	0.046 mg/L
Tetrachloroethylene	Aquifer	(EMU) 1987–1993 (SS) 1987, 1989–1991	<0.2 to 4.5 μg/L <0.2 to 3.0 μg/L
	Air	(SS) 1994	4.2 μg/m³
	Perched water	(EMU) 1987–1990 (SS) 1987, 1988, 1990–1991, 1993	4.5 to 1,200 μg/L <0.2 to 230 μg/L
	Soil/borehole vapor	(SS) 1987, 1992	BDL to 62 μg/L
	Soil/soil vapor	(SS) 1987	3 to 40 μg/L
Toluene	Aquifer	(EMU) 1987–1993 (SS) 1987, 1988, 1990, 1991	<0.2 to <1.0 μg/L <0.2 to 3.0 μg/L
	Air	(SS) 1994	0.3 μg/m³
	Perched water	(EMU) 1987–1990 (SS) 1987-1988, 1990–1991, 1993	<0.2 to 0.3 μg/L <0.2 to 100 μg/L
	Soil/borehole vapor	(SS) 1987, 1992	0.3 to 191 μg/L

Table F-2. (continued).

Contaminant	Medium	Years in which contaminant was detected[a]	Concentration
Trichloroethylene	Aquifer	(EMU) 1987–1993 (SS) 1987–1988	<0.2 to 1.4 μg/L <0.2 to 860 μg/L
	Perched water	(EMU) 1987–1990 (SS) 1987–1988, 1990–1991, 1993	BDL to 860 μg/L <0.2 to 1,600 μg/L
	Air	(SS) 1987, 1989	11 to 380 mg/m^3
	Soil/borehole vapor	(SS) 1987, 1992	BDL to 690 μg/L
	Sedimentary interbed	(SS) 1987	81 μg/kg
METALS			
Antimony	Perched water	(SS) 1988, 1993	2.2 to 70.0 μg/L
Arsenic	Aquifer	(SS) 1987	1 to 14.3 μg/L
	Perched water	(SS) 1988, 1993	<2.0 to 4.2 μg/L
Barium	Sedimentary interbed	(SS) 1987	392 mg/kg
	Perched water	(SS) 1988, 1993	18 to 1,260 μg/L
Beryllium	Perched water	(SS) 1988, 1993	<0.5 to 6.4 μg/L
	Subsurface soil	(SS) 1991	1.9 to 2.7 mg/kg
	Sedimentary interbed	(SS) 1987	1.4 mg/kg
Boron	Surface soil	(SS) 1982	190 mg/kg
Cadmium	Perched water	(SS) 1988, 1993	<1 to 16.1 μg/L
	Surface soil	(SS) 1982	0.50 mg/kg
Chromium	Surface water	(EMU) 1986	2.2±0.1 mg/L
	Aquifer	(SS) 1985–1986, 1987	0.05 to 56±10 μg/L
	Perched water	(SS) 1993	<6.0 to 50 μg/L
	Sedimentary interbed	(SS) 1987	40.0 mg/kg
	Soil	(SS) 1982	3.5 mg/kg
Cobalt	Perched water	(SS) 1988, 1993	<12.0 to 72.4 μg/L

Table F-2. (continued).

Contaminant	Medium	Years in which contaminant was detected[a]	Concentration
Copper	Perched water	(SS) 1988, 1993	<7.0 to 10.8 μg/L
	Soil	(SS) 1982	6.9 mg/kg
	Sedimentary interbed	(SS) 1987	30.3 mg/kg
Lead	Perched water	(SS) 1988, 1993	<5 to 21.5 μg/L
	Surface soil	(SS) 1982	8.8 mg/kg
Mercury	Subsurface soil	(SS) 1991	1.40 to 5,320 mg/kg[b]
	Perched water	(SS) 1988, 1993	<0.1 to 3.4 μg/L
	Soil vapor	(SS) 1990	ND
	Sedimentary interbed	(SS) 1987	0.6 mg/kg
Nickel	Sedimentary interbed	(SS) 1987	34.4 mg/kg
	Perched water	(SS) 1988, 1993	9 to 996 μg/L
Selenium	Sedimentary interbed	(SS) 1987	1.0 mg/kg
	Subsurface water	(SS) 1987, 1988	ND to 3 μg/L
	Perched water	(SS) 1993	1.1 to 97.9 μg/L
Silver	Sedimentary interbed	(SS) 1987	2.4 mg/kg
	Perched water	(SS) 1988, 1993	<1 to 1.6 μg/L
Thallium	Sedimentary interbed	(SS) 1987	2.4 mg/kg
	Perched water	(SS) 1988, 1993	0.9 μg/L
Tin	Sedimentary interbed	(SS) 1987	244 mg/kg
	Perched water	(SS) 1988	1,000 μg/L
Vanadium	Sedimentary interbed	(SS) 1987	53.3 mg/kg
	Perched water	(SS) 1988, 1993	<15.0 to 16.4 μg/L
Zinc	Surface soil	(SS) 1982	37.0 mg/kg
	Perched water	(SS) 1988, 1993	4.3 to 945 μg/L
	Sedimentary interbed	(SS) 1987	2.4 mg/kg

Table F-2. (continued).

Contaminant	Medium	Years in which contaminant was detected[a]	Concentration
OTHER[c]			
Chloride	Aquifer	(EMU) 1979, 1982-1993	9 ± 1 to 105 ± 11 ppm
	Perched water	(EMU) 1982-1993 (SS) 1993	62 ± 6 to 93 ± 9 ppm 4,980 to 635,000 μg/L
	Surface soil	(SS) 1982	150 mg/kg
Cyanide	Perched water	(SS) 1988	5 μg/L
	Sedimentary interbed	(SS) 1987	1.25 mg/kg
Nitrate	Aquifer	(EMU) 1982, 1983, 1987	0.5 to 12 mg/L
	Perched water	(SS) 1993	130 to 2,040 μg/L
	Surface water	(EMU) 1980-1982	0.08 to 4.7 mg/L
	Surface soil	(EMU) 1980-1983 (SS) 1982	1-49 ppm 0.28 mg/kg
Sodium ion	Surface water	(EMU) 1983-1986	6 to 100 ± 10 mg/L
	Aquifer	(EMU) 1979, 1982-1993	6 ± 1 to 52 ± 5 ppm
	Perched water	(EMU) 1985-1987, 1992	BDL to 100 ± 10 ppm
Sulfate	Perched water	(SS) 1988	1 μg/L
	Perched water	(SS) 1993	6,290 to 40,800 μg/L
	Perched water	(SS) 1985	19.95 μg/L
Sulfide	Sedimentary interbed	(SS) 1987	200 mg/kg

a. Concentrations included in this table were actually detected in those years indicated. Occasionally, contaminants were monitored during a year, but the analyses were not available for inclusion in the annual EMU report.

b. Detections involved drilling directly into a disposal unit.

c. Contaminant monitoring occurred from 1976 through 1993.

BDL — Below detection limit.
EMU — Data compiled from routine monitoring results published by the Environmental Monitoring Unit.
ND — Not detected.
NR — Minimum measured concentration was not reported in the reference source practical quantitation limit.
PQL — Practical quantitation limit.
SS — Special studies. Data compiled from studies other than those that are part of the routine monitoring program at the SDA.

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